"STABILIZATION OF BLACK COTTON SOIL USING LIME AND GEOCOMPOSITE"

A PROJECT

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BACHELOR OF TECHNOLOGY

IN

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Under the supervision of

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to

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CERTIFICATE

This is to certify that the work which is being presented in the project title **"STABILIZATION OF BLACK COTTON SOIL USING LIME AND GEOCOMPOSITE"** in partial fulfillment of the requirements for the award of the degree of Bachelor of technology and submitted in Civil Engineering Department, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Utsav Khandelwal (121681)** and **Rohn Negi (121691)** during a period from July 2015 to June 2016 under the supervision of **Lav Singh**, Assistant Professor, Civil Engineering Department, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of my knowledge.

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Abstract

Bricks have been regarded as one of the strongest building material used throughout history. Ordinary building blocks are made of a mixture of clay, which is subjected to various processes, different according to the nature of the material, after being properly prepared the clay is formed in moulds to the desired shape, then dried and burnt. Local soil has always been the most widely used material for earthen construction. The main objective of this investigation had been focused on the improvement of the compressive strength of the black cotton soil blocks with different content of lime by reinforcing the geocomposite. The cubical (100mm × 100mm × 100mm) blocks are prepared with soil treated with 5%, 10% and 15% lime with one and two layers of geocomposite reinforcement inside the blocks, the compressive strength of the bricks is obtained by laboratory compression test apparatus the results obtained are compared with unreinforced samples.

Expansive soils are causing number of damages to the structures particularly light buildings and pavements compare to other natural hazards like earthquake, floods, etc. Thus, worldwide these soils are considered to be problematic soils and pose several challenges for engineers. So, as to utilize these soils in an effective way, proper treatment to the soil is required. With the same intention, an attempt is made to modify engineering properties of black cotton soils

Keywords—Black Cotton Soil, Lime, Geo-composite, Compressive strength, Cubical blocks

CHAPTER 1: INTRODUCTION

1.1 GENERAL

Soil is one of the major natural resources, like air and water. It is the topmost layer of the earth's crust and is a mixture of fine powdered rocks, organic matter, liquids, myriad organisms and other minerals. It acts as an interface between hydrosphere, lithosphere, earth's atmosphere and biosphere. The proportion of the key ingredients determines the type of soil. But, factors such as vegetation, climatic conditions, human activities for e.g. grazing, farming, gardening etc. also influence soil formation. In India, various types of soils are found and their formations are influenced by certain factors such as altitude, climate disproportionate rainfall and many others. The type of soil differs in different areas of the country. The major types of soils found in India are:

1. **Laterite Soil:** The laterite soil is found in those regions of the country which receive heavy rainfall with alternate dry and wet period. In these climatic conditions, leaching of soil takes place which is a process in which fertile portion of the soil gets washed away by heavy rains. They are formed from the decomposition of rocks and contain iron oxide which gives them red or pink colour. This type of soil is normally deficient in nitrogen and is poor in lime content. This type of soil is found in several parts of the country mainly Western and Eastern Ghats, Vindhyas, Malwa plateau and Satpuras. The states where this type of soil can be found are West Bengal, Andhra Pradesh, Bihar, Meghalaya, Assam, Odisha to name a few.

2. **Mountain Soils:** Mountain soils are formed due to the accumulation of organic matter which is derived from the forest growth. This type of soil is rich in humus but has poor lime, potash and phosphorus content. It is generally sandy and has gravels. It is mainly found in Himalayan region of the country. Maize, barley, wheat and temperate fruits are grown in this soil in the Himalayan region. Plantation of crops like tropical fruits, coffee, tea or spices in states of south India like Kerala, Tamil Nadu and Karnataka are undertaken in this type of soil.

3. **Black Soil:** This type of soil is made up of volcanic rocks and lava. Black soil is also known as 'regur' which is derived from a Telugu word 'reguda'. Black soil is also known as Black Cotton Soil as cotton is an important crop which is grown in this type of soil. The soil content is rich in calcium carbonate, potash, lime and magnesium carbonate but has poor phosphorus content. It is mostly found in areas such as Gujarat, Madhya Pradesh and Maharashtra. It is also found in states like Tamil Nadu, Andhra Pradesh and Karnataka.

4. **Red Soil:** This type of soil is formed as a result of weathering of metamorphic and igneous rocks. The red colour of the soil comes from the high percentage of iron content. The soil's texture varies from being sandy to clayey, but it is mainly loamy. It is rich in potash content but lacks phosphate, humus and nitrogen content. The red soil is found in regions such as Tamil Nadu, Madhya Pradesh, Jharkhand, Odisha, some parts of Karnataka and southeast Maharashtra.

5. **Alluvial Soil:** Alluvial soils are formed by the deposits of the sediments brought by rivers. Most of the rivers originate from the Himalayas and bring along high amount of sediments with them. The soil is made up of particles like silt, sand and clay. It has adequate amount of phosphoric acid, potash and lime. Alluvial soil is of two types - (i) old alluvium known as bangar, and (ii) new alluvium called khaddar. It is the most important type of soil found in the country as it covers about 40% of the total land. It is found in the areas of northern plains beginning from Punjab to West Bengal and Assam. It is also found in deltas of different rivers such as Krishna, Godavari, Kaveri and Mahanadi in peninsular India.

6. **Desert Soil:** The desert soil is found in regions with low rainfall. The sand in the desert areas is partly original and partly blown from Indus Valley. The soil content has 90-95% of sand and 5-10% of clay. The phosphate content in the soil is high while the nitrogen content is low. The water content in the soil is fulfilled through irrigation. This type of soil is found in arid and

semi-arid areas. Desert soil is found mostly in areas of Rajasthan, and also in Haryana and Punjab.

7. **Saline and Alkaline Soil:** There are many mineral based and undecomposed contents inside the earth. Due to weathering, they release certain minerals such as magnesium, sodium, sulphurous acid and calcium salts. Some of the released salts get carried in solution by rivers and mix in sub-soils of the plains making the soils saline and alkaline. This type of soil can be found in Uttar Pradesh and Punjab and also in some parts of Gujarat.

8. **Peat Soil:** Accumulation of high amount of organic matters in the soil in humid regions results in the formation of peaty soils. These types of soils constitute about 10 to 40% of the organic matter and also a reasonable amount of soluble salts. Peaty soils are heavy, black in colour and have high acidic content. They are low in phosphate and potash content. Peaty and marshy soils are found in a few districts of Kerala. On the other hand, marshy soils are found in coastal areas of some states such as Tamil Nadu, Bihar, Almora district of Uttaranchal and Sunderbans of West Bengal.

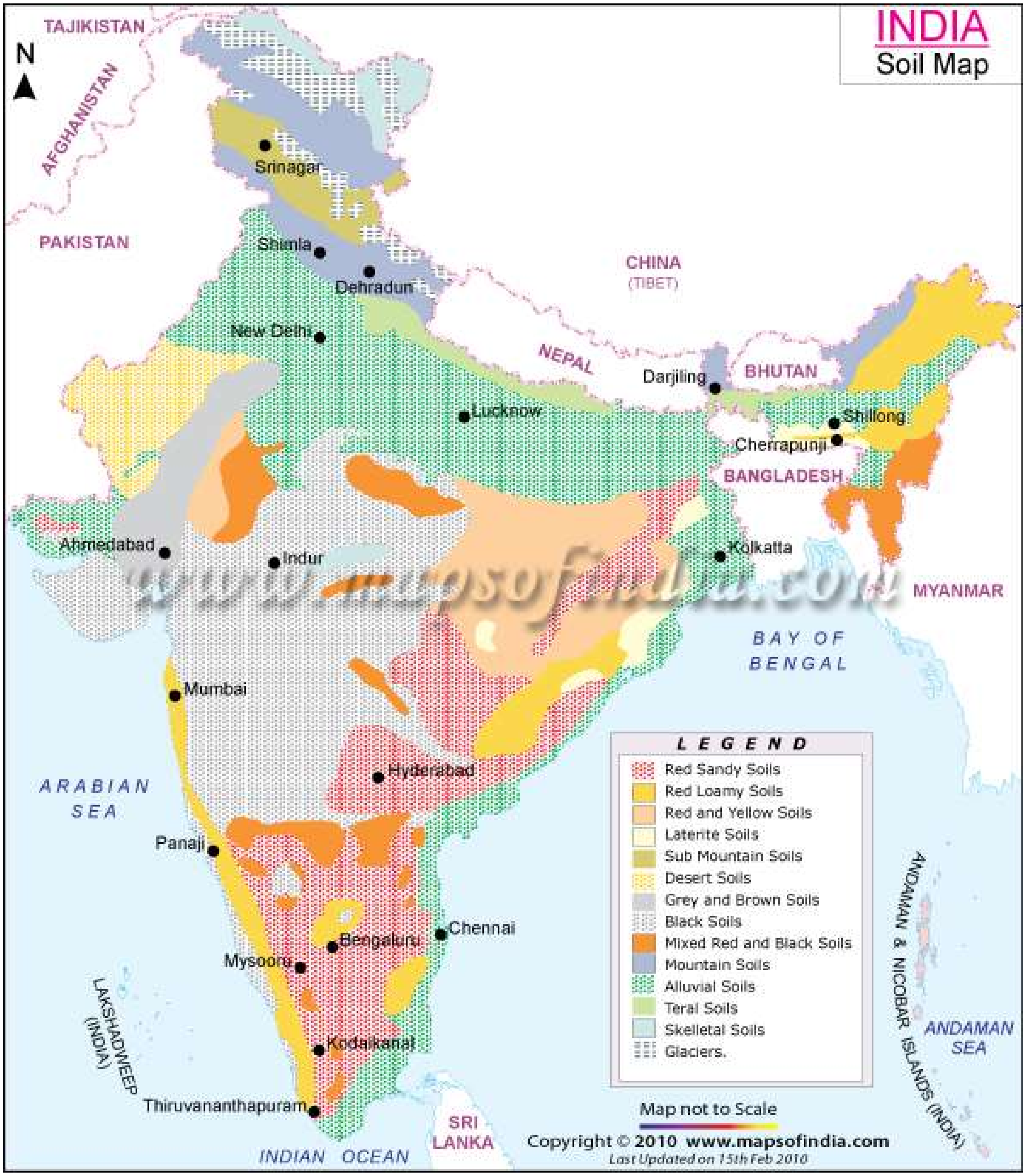

Fig 1. Soil Map of India

1.2 BLACK COTTON SOIL

Black soils, locally called regard or black cotton soils, and internationally known as 'tropical black earths' or 'tropical chernozems' have been developed by the weathering of the Deccan lava in major parts of Maharashtra, western Madhya Pradesh (Hoshangabad, Narsinghpur, Damoh, Jabalpur, Raisen and Shahdol districts), Gujarat (Surat, Bharuch, Vadodara, Kheda, Sabarkantha and Dang districts), Andhra Pradesh (Adilabad, Warangal, Khammam, Mahbubnagar, Kurnool, Guntur and Karimnagar districts), Karnataka (Bijapur, Dharwar, Gulbarga, Bidar, Belgaum, Raichur, Bellari and Chitradurga districts), Rajasthan (Kota, Bundi, Sawai Madhopur, Bharatpur and Banswara districts), Tamil Nadu (Ramnathpuram, Tirunelvelli, Coimbatore, Madurai and South Arcot districts) and Uttar Pradesh (Jalaun, Hamirpur, Banda and Jhansi districts).

According to Krebs the regur soil is essentially a mature soil which has been produced by relief and climate rather than by a particular type of rock. **It occurs where the annual rainfall is between 50 cm to 75 cm and the number of rainy days is from 30 to 50**.

The colour of these soils varies from deep black to light black and chestnut and is dependent on the colour of the mechanical fractions.

The black color is attributed to the presence of titaniferous magnetite, compounds of iron and aluminum, accumulated humus and colloidal hydrated double iron and aluminum silicate. In general these soils have clay texture, **average clay content being 50%** and **the range being 40-50%**. Except in cases where there is stratification, the clay content down the profile is uniform.

The structure of these soils is usually cloddish but occasionally friable. Regard soils are calcareous neutral to mild alkaline in reaction, high in carbon exchange capacity and low in organic matter. In general these soils are rich in iron, lime, calcium, potash, aluminum and magnesium carbonates but poor in nitrogen, phosphorus and organic matter. The chemical test near Nagpur yields soluble matter 68.71%, ferric oxide 11.24%, alumina 9.3%, water and organic matter 5.83%, lime 1.81% and magnesium 1.79%.

Black soils are highly retentive of moisture, extremely compact and tenacious when wet, considerably contracted developing deep wide cracks on drying and self-ploughing. Black soils are credited with high fertility. These are well suited to leguminous crops like cotton, turn and citrus fruits. Other crops include wheat, jowar, millets, linseed, castor, tobacco, sugarcane, safflower, vegetables etc. On the uplands these soils are comparatively less fertile than on the low lands.

1.2.1 Classification

On the basis of the proportion of clay and silt regard soils are divided into two broad groups:

a) **Trappean Black Clayey Soil** - it occupies major parts of the Peninsular India. This soil is very heavy owing to finer constituents (65% to 80%).

b) **Trappean Black Loamy Soil** - in this soil the silt-content varies between 30 and 40 per cent. It occurs in patches in the Wainganga valley and northern Konkan coast.

Based on the thickness of layers black soils may be divided into three sub-groups:

a) **Shallow Black Soil** - its thickness is less than 30 cm. It mainly occupies Satpura hills (Madhya Pradesh), Bhandara, Nagpur and Satara (Maharashtra), Bijapur and Gulbarga districts (Karnataka). The soil is utilised in the cultivation of jowar, rice, wheat, gram and cotton.

b) **Medium Black Soil** - its thickness ranges between 30 cm and 100 cm. It covers a larger area in Maharashtra, Gujarat, Madhya Pradesh, Tamil Nadu and Andhra Pradesh.

c) **Deep Black Soil** - its thickness is more than 1 meter. It covers large areas in lowland zones of the Peninsular India. The clay content ranges between 40 to 60 per cent. Its reaction is alkaline. The soil is fertile and is utilised in raising the crops of cotton, sugarcane, rice, citrus fruits, vegetables etc.

Similarly on the basis of the colour we may have

a) **deep coloured**, and

b) **light coloured** black soils.

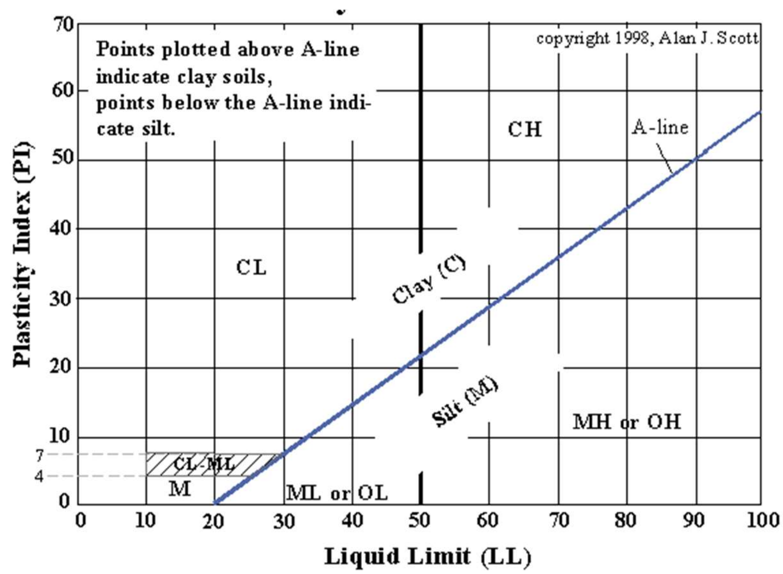

Fig 2: Plasticity Chart for USCS

1.3 DEFECTS OF BLACK COTTON SOIL

Though black cotton soils are very fertile soils, they are not good as road or construction foundation. Black cotton soils are expansive clays with high potential for shrinking or swelling as a result of changing moisture content. Due to intensive shrink-swell processes, surface cracks resulting in openings during dry seasons. These openings are usually more than 50mm wide and several millimeters deep. Cracks disappear during wet season but an uneven soil surface stays as a result of irregular swelling and heaving. The black cotton soils have low strength and are susceptible to excessive volume changes, making their use for construction purposes very difficult. Instability of these soils cause more damage to structures, than any other natural hazard, including earthquakes and floods, unless proper black cotton soil stabilization performed.

A small amount of rainfall, such as 6mm can make these soils impassable for all traffic. Due to plastic nature, the black cotton soils stick onto wheels, animals' feet, clog cultivation machines, and are hard to remove. Expansive nature of this soil negatively affects its bearing capacity. When dry, black cotton soil is so hard that the clods cannot be easily pulverized for treatment for its use in road construction. This leads to serious problems related to consequent performance of the road.

1.4 STABILIZATION OF BLACK COTTON SOIL

Replacement of expansive soil with a non-expansive material is a common method of reducing shrink-swell risk. In the case when expansive soil or stratum is thin, then the entire layer can be removed. However, often the soil or stratum extends too deep and in that case this method is not economically efficient.

One of methods of black cotton soil stabilization is wetting in order to saturate soil and thus prevent potential expansion if the high moisture content can be maintained. Soils with low hydraulic conductivity may take years to saturate. On the other hand soils with high hydraulic conductivity may never become sufficiently wet. Therefore, this method is not efficient for many black cotton soils.

Lime stabilization has been used extensively in black cotton soil stabilization. The addition of lime results in several stabilizing reactions. The solubility of silica increases in alkaline environment and silica becomes available as a cementing agent. The lime also provides a divalent cation which forms Casilicates and Ca-Al hydrates that increase soil strength. However, if soil contains organics, sulfates, and some iron compounds, lime stabilization reactions can be inhibited.

On many construction sites, good quality materials and additives are unavailable or they are in shortage. Because of this reason, engineers are often forced to search alternative designs using substandard materials, commercial construction aids, and innovative design practices. One category of **commercial construction aids is geo-synthetics**, which is a manmade material made from various types of polymers and used to enhance geotechnical properties of soil. Various types of geo-synthetics are: geo-textiles, geo-grids, geo-nets, geo-foam, geo-membranes, geo-composites etc. The polymeric nature of the products makes them suitable for use in the soil where high levels of durability are required. Geo-synthetics perform five major functions such as separation, reinforcement, filtration, drainage, and moisture barrier. One category of geo-synthetics in particular is geo-grids, which is used for improving the engineering properties of soil.

1.5 GEOSYNTHETICS

Geosynthetics are synthetic products used to stabilize terrain. They are generally polymeric products used to solve civil engineering problems. This includes eight main product categories: geotextiles, geogrids, geonets, geomembranes, geosynthetic clay liners, geofoam, geocells and geocomposites.

The polymeric nature of the products makes them suitable for use in the ground where high levels of durability are required. They can also be used in exposed applications. Geosynthetics are available in a wide range of forms and materials. These products have a wide range of applications and are currently used in many civil, geotechnical, transportation, geoenvironmental, hydraulic, and private development applications including roads, airfields, railroads, embankments, retaining structures, reservoirs, canals, dams, erosion control, sediment control, landfill liners, landfill covers, mining, aquaculture and agriculture.

Geosynthetics have many uses. Sustainable development and environment protection can go hand - and - hand. It reduces maintenance cost and increases life. It saves substantial cost over alternative solutions. The quality can be controlled as manufactured in a factory. It is widely available. It has generic specifications and easy to install**.**

It has excellent stress-strain behaviour. It has good flexibility. It has excellent filtration characteristics. It has high water permeability. It can provides excellent mechanical protection. It can be welded together. It does not form by-products. It is highly resistant to chemical and biological attack, and. It is chemically ultraviolet stabilized.

1.5.1 CATEGORIES OF GEOSYNTHETICS

1.5.1.1 Geotextiles

Geotextiles form one of the two largest groups of geosynthetics. They are textiles consisting of synthetic fibers rather than natural ones such as cotton, wool, or silk. This makes them less susceptible to bio-degradation. These synthetic fibers are made into flexible, porous fabrics by standard weaving machinery or are matted together in a random non woven manner. Some are also knitted. Geotextiles are porous to liquid flow across their manufactured plane and also within their thickness, but to a widely varying degree. There are at least 100 specific application areas for geotextiles that have been developed; however, the fabric always performs at least one of four discrete functions: separation, reinforcement, filtration, and/or drainage.

1.5.1.2 Geogrids

Geogrids represent a rapidly growing segment within geosynthetics. Rather than being a woven, nonwoven or knitted textile fabric, geogrids are polymers formed into a very open, gridlike configuration, i.e., they have large apertures between individual ribs in the transverse and longitudinal directions. Geogrids are (a) either stretched in one, two or three directions for improved physical properties, (b) made on weaving or knitting machinery by standard textile manufacturing methods, or (c) by laser or ultrasonically bonding rods or straps together. There are many specific application areas; however, geogrids function almost exclusively as reinforcement materials.

1.5.1.3 Geonets

Geonets, and the related *geospacers* by some, constitute another specialized segment within the geosynthetics area. They are formed by a continuous extrusion of parallel sets of polymeric ribs at acute angles to one another. When the ribs are opened, relatively large apertures are formed into a netlike configuration. Two types are most common, either biplanar or triplanar. Alternatively many very different types of drainage cores are available. They consist of nubbed, dimpled or cuspated polymer sheets, three-dimensional networks of stiff polymer fibers in different configurations and small drainage pipes or spacers within geotextiles. Their design function is completely within the drainage area where they are used to convey liquids or gases of all types.

1.5.1.4 Geomembranes

Geomembranes represent the other largest group of geosynthetics, and in dollar volume their sales are greater than that of geotextiles. Their growth in the United States and Germany was stimulated by governmental regulations originally enacted in the early 1980s for the lining of solid-waste landfills. The materials themselves are relatively thin, impervious sheets of polymeric material used primarily for linings and covers of liquids- or solid-storage facilities. This includes all types of landfills, surface impoundments, canals, and other containment facilities. Thus the primary function is always containment as a liquid or vapor barrier or both. The range of applications, however, is great, and in addition to the environmental area, applications are rapidly growing in geotechnical, transportation, hydraulic, and private development engineering (such as aquaculture, agriculture, heap leach mining, etc.).

1.5.1.5 Geosynthetic clay liners

Geosynthetic clay liners, or GCLs, are an interesting juxtaposition of polymeric materials and natural soils. They are rolls of factory fabricated thin layers of bentonite clay sandwiched between two geotextiles or bonded to a geomembrane. Structural integrity of the subsequent composite is obtained by needle-punching, stitching or adhesive bonding. GCLs are used as a composite component beneath a geomembrane or by themselves in geoenvironmental and containment applications as well as in transportation, geotechnical, hydraulic, and many private development applications.

1.5.1.6 Geofoam

Geofoam is a product created by a polymeric expansion process of polystyrene resulting in a “foam” consisting of many closed, but gas-filled, cells. The skeletal nature of the cell walls is the unexpanded polymeric material. The resulting product is generally in the form of large, but extremely light, blocks which are stacked side-by-side providing lightweight fill in numerous applications.

1.5.1.7 Geocells

Geocells (also known as Cellular Confinement Systems) are three-dimensional honeycombed cellular structures that form a confinement system when infilled with compacted soil. Extruded from polymeric materials into strips welded together ultrasonically in series, the strips are expanded to form the stiff (and typically textured and perforated) walls of a flexible 3D cellular mattress. Infilled with soil, a new composite entity is created from the cell-soil interactions. The cellular confinement reduces the lateral movement of soil particles, thereby maintaining compaction and forms a stiffened mattress that distributes loads over a wider area. Traditionally used in slope protection and earth retention applications, geocells made from advanced polymers are being increasingly adopted for long-term road and rail load support. Much larger geocells are also made from stiff geotextiles sewn into similar, but larger, unit cells that are used for protection bunkers and walls.

1.5.1.8 Geocomposites

A geocomposite consists of a combination of geotextiles, geogrids, geonets and/or geomembranes in a factory fabricated unit. Also, any one of these four materials can be combined with another synthetic material (e.g., deformed plastic sheets or steel cables) or even with soil. As examples, a geonet or geospacer with geotextiles on both surfaces and a GCL consisting of a geotextile/bentonite/geotextile sandwich are both geocomposites. This specific category brings out the best creative efforts of the engineer and manufacturer. The application areas are numerous and constantly growing. The major functions encompass the entire range of functions listed for geosynthetics discussed previously: separation, reinforcement, filtration, drainage, and containment.

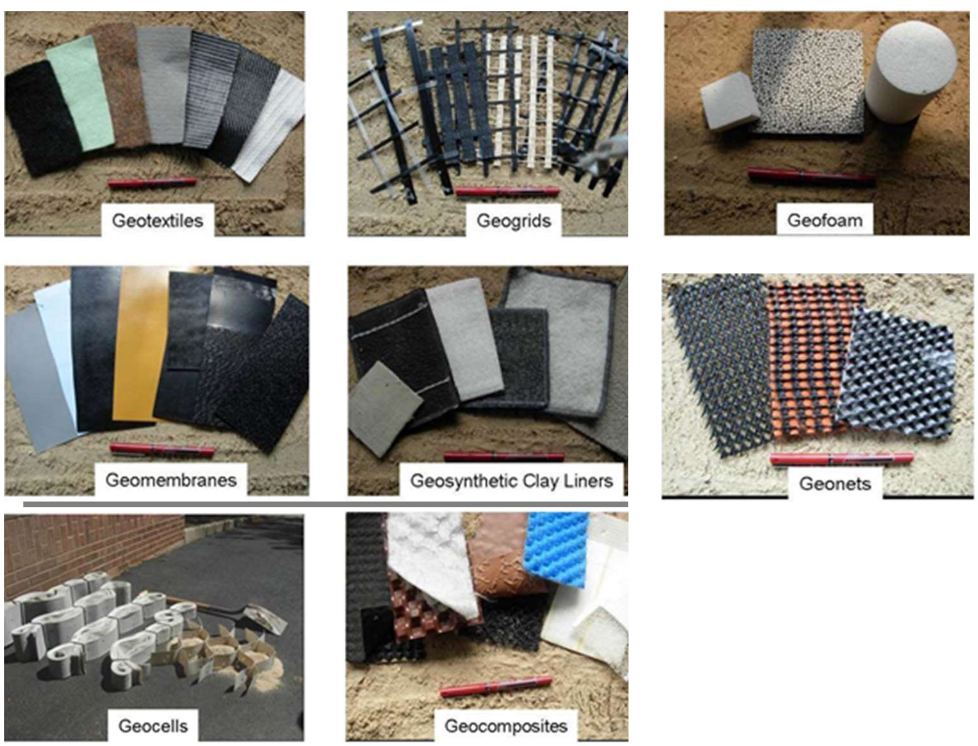

Fig 3.Categories of Geosynthetics

1.6 GEOCOMPOSITE

The basic philosophy behind geocomposite materials is to **combine the best features of different materials** in such a way that specific applications are addressed in the optimal manner and at minimum cost. Thus, **the benefit/cost ratio is maximized**. Such geocomposites will generally be geosynthetic materials, but not always. In some cases it may be more advantageous to use a nonsynthetic material with a geosynthetic one for optimum performance and/or least cost. As seen in the following, the number of possibilities is huge — the only limits being one's ingenuity and imagination. There are five basic functions that can be provided: **separation, reinforcement, filtration, drainage, and containment.**

1.6.1 TYPES OF GEOCOMPOSITES

1.6.1.1 Geotextile-geonet composites

When a geotextile is used on one or both sides of a geonet, the separation and filtration functions are always satisfied, but the drainage function is vastly improved in comparison to geotextiles by themselves. Such geocomposites are regularly used in intercepting and conveying leachate in landfill liner. These drainage geocomposites also make excellent drains to intercept water in a capillary zone where frost heave or salt migration is a problem. In all cases, the liquid enters through the geotextile and then travels horizontally within the geonet to a suitable exit.

1.6.1.2 Geotextile-geomembrane composites

Geotextiles can be laminated on one or both sides of a geomembrane for a number of purposes. The geotextiles provide increased resistance to puncture, tear propagation, and friction related to sliding, as well as providing tensile strength in and of themselves. Quite often, however, the geotextiles are of the nonwoven, needle-punched variety and are of relatively heavy weight. In such cases the geotextile component acts as a drainage media, since its in-plane transmissivity feature can conduct water, leachate or gases away from direct contact with the geomembrane

1.6.1.3 Geomembrane-geogrid composites

Since some types of geomembranes and geogrids can be made from the same material (e.g., high-density polyethylene), they can be bonded together to form an impervious membrane barrier with enhanced strength and friction capabilities.

1.6.1.4 Geotextile-geogrid composites

A needle punched nonwoven geotextile bonded to a geogrid provides in-plane drainage while the geogrid provides tensile reinforcement. Such geotextile-geogrid composites are used for internal drainage of low-permeability backfill soils for reinforced walls and slopes. The synergistic properties of each component enhances the behavior of the final product.

1.6.1.5 Geotextile-polymer core composites

A core in the form of a quasi-rigid plastic sheet, it can be extruded or deformed in such a way as to allow very large quantities of liquid to flow within its structure; it thus acts as a drainage core. The core must be protected by a geotextile, acting as a filter and separator, on one or both sides. Various systems are available, each focused on a particular application. The 100 mm wide by 5 mm thick polymer cores are often fluted for ease of conducting water. The emergence of such wick drains, or PVDs, has all but eliminated traditional sand drains as a rapid means of consolidating fine-grained saturated cohesive soils.

The second type is in the form of drainage panels, the rigid polymer core being nubbed, columned, dimpled or a three-dimensional net. With a geotextile on one side it makes an excellent drain on the backfilled side of retaining walls, basement walls and plaza decks. As with wick drains, the geotextile is the filter/separator and the thick polymer core is the drain. Many systems of this type are available, the latest addition having a thin pliable geomembrane on the side facing the wall and functioning as a vapor barrier.

The third type within this area of drainage geocomposites is the category of prefabricated edge drains. These materials, typically 500 mm high by 20 to 30 mm wide are placed adjacent to a highway pavement, airfield pavement, or railroad right-of-way, for lateral drainage out of and away from the pavement section. The systems are very rapid in their installation and extremely cost effective.

CHAPTER 2: LITERATURE REVIEW

1. **Vinayak Kaushal, Dr. S. P. Guleria (Deptt. of Civil Engineering, Jawaharlal Nehru Government Engineering College, Sundernagar, India)** studied Black cotton soils which were derived from Indrasagar Rockfill Dam, Polavaram, Andhra Pradesh (India) from a depth of 1m, 1.2 m and 1.5 meters. Physical and geotechnical properties of the soil samples were studied in the laboratory. The tests conducted were grain size analysis, specific gravity, atterberg's limits, standard Proctor compaction, consolidation and direct shear test. Results as obtained were compared with the Indian standard code.

Properties	Soil A	Soil B	Soil C	Recommended values as per IS 1498-1970
Liquid Limit	48.66	40.8	38.2	35-50
Plastic Limit	26.61	20.3	18.2	Less than or equal to 40
Plasticity Index	22.08	20.5	20	Greater than 10
Specific Gravity	2.76	2.70	2.68	2.72
Optimum Moisture Content	19.6	17.7	17.2	Up to 21%
Maximum Dry Density	1.92	1.71	1.67	1.92
Angle of Internal Friction (degree)	26.400	28.800	30.200	25-35
Cohesion (KN/m^2)	18	16.2	14.5	12-24
Compression Index	0.3380	0.2772	0.2538	0.225-0.360

Table 1. Properties of soil and their values

CONCLUSIONS

The values of the various geotechnical characteristics of the black cotton soil are well under the specified values as per IS 1498-1970. The values of liquid limit and plastic limit are 35-40 and less than 40 respectively as recommended by IS 1498-1970. The value of plasticity index is greater than 10 and optimum moisture content is upto 21%.

The values of the various geotechnical properties that will be found from our experiments will be checked from the specified values as per IS 1498-1970 in this paper.

2. **Sujit Kawade, Mahendra Mapari (Civil Department GSMCOE, University of Pune)** conducted this investigation by focusing on the improvement of the compressive strength of the black cotton soil blocks with different content of lime by reinforcing the geo-grid. The rectangular (200mm × 100mm × 100mm) blocks are prepared with soil treated with 5%, 10% and 15% lime with the geo-grid reinforcement at the middle depth of the blocks, the compressive strength of the bricks is obtained by laboratory compression test apparatus the results obtained are compared with unreinforced samples.

Figure 4(a). Variation of compressive strength of BC soil blocks without Geo-grid reinforcement for various days of curing

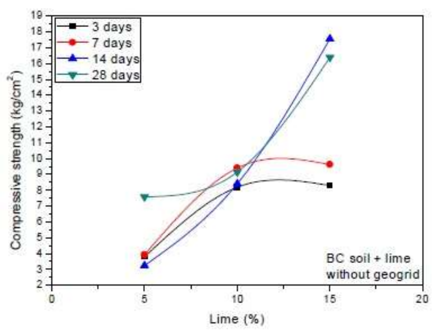

Fig 4(a)

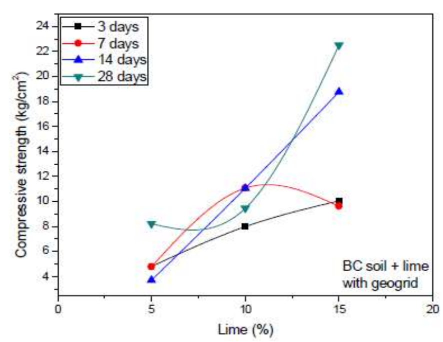

Fig 4(b)

Figure 4(b). Variation of compressive strength of BC soil blocks with Geo-grid reinforcement.

The graph is plotted against CS of BC soil blocks with geo-grid reinforcement and % of lime for various days of curing period.

CONCLUSIONS

With the increase in addition of lime the compressive strength of black cotton soil increases. The soil liquid limit and plastic limit values are 66.1% and 36.74% respectively. It suggest that the soil is highly compressible. The soil is not recommended for most geotechnical work. Lime and geo-grid when used as reinforcement significantly improves the geotechnical characteristics of black cotton soil. The compressive strength of these soils increases upon the addition of lime. Curing significantly increases the compressive strength of black cotton soil blocks. 14 days curing have yield the maximum enhancement in the compressive strength of blocks with 15% lime content. And 28 days curing yield maximum strength with lime and geo-grid.

3. **Kavish S. Mehta, Rutvij J. Sonecha, Parth D. Daxini, Parth B. Ratanpara, Miss Kapilani S. Gaikwad (Student, Department of Civil Engineering, L.T.I.E.T, Gujarat Technological University, Rajkot-05)** conducted this investigation for Improvement of bearing capacity of Black Cotton Soil on addition of lime. Variation of Strength of soil at different water content. Effect of lime on CBR value of the soil. Effect of lime on Compressive strength of soil

The results from various experiments

Liquid Limit = 58%

Plastic Limit = 28%

From laboratory test results they got value of C.B.R at different readings. for design of flexible pavement as per I.R.C 37-2001,value of C.B.R is very poor is less than 4%. And the swelling pressure is 9 kg/cm^2

CONCLUSIONS

From the results we conclude that the value of liquid limit and plastic limit is very high and high content of water so this soil cannot be used directly for the construction purpose. As the value of optimum moisture content is high, it has low dry density and there are air voids in the soil. So the soil soil has tendency to lose its strength .The value of CBR is less and swelling pressure is high so the soil has no high strength and no stabilization. So the soil is stabilized by lime which increase the strength of soil, and decrease the swelling pressure of and decrease the liquid limit and plastic limit. After addition of lime the results which they got showed significant improvement in the values of geotechnical characteristics of soil. So the addition of lime can be used in large projects.

The addition of lime in black cotton soil hence shows a large amount of improvement in various properties of the soil and hence we will use lime for stabilization of black cotton soil that we will use for the project.

4. **K.V. Madurwar, P.P. Dahale, A.N.Burile (Asst. Prof., Dept. of Civil Engg., Bhagwati Chaturvedi College of Engineering, Nagpur, Maharashtra, India)** conducted their study on black Soil that was collected from Katol road area of Nagpur city. Tests were carried out to determine the various properties of soil. And the main focus was in the improvement of various geotechnical properties of soil by adding **RBI 81** and **SODIUM SILICATE**

TEST RESULTS WITH RBI GRADE 81 AND SODIUM SILICATE

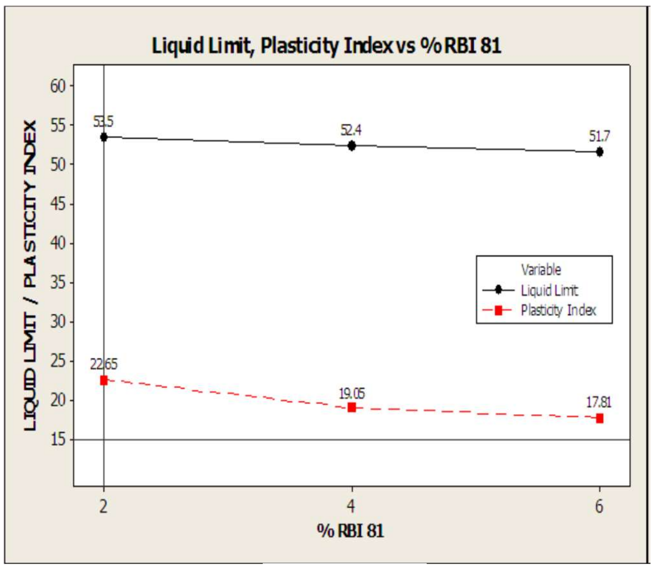

Fig 5(a)

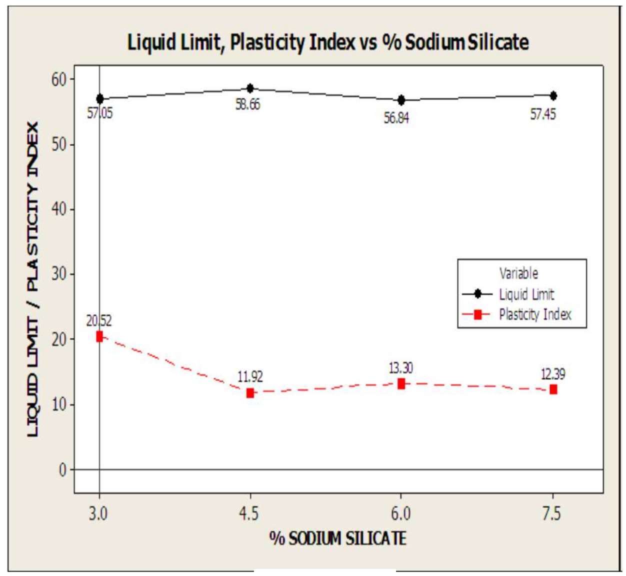

Fig 5(b)

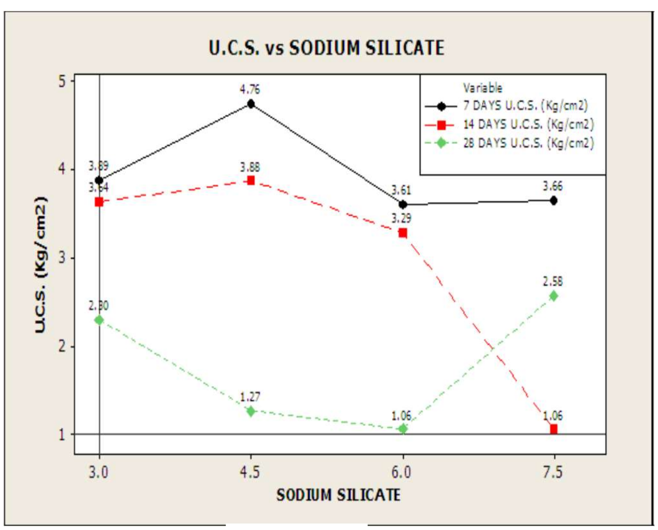

Fig 5(c)

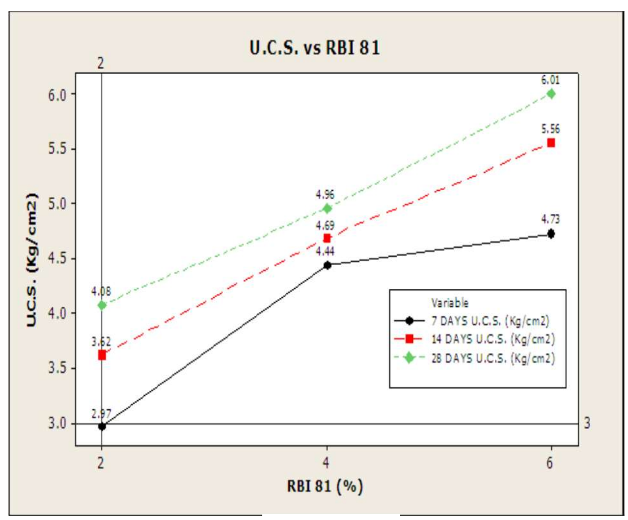

Fig 5(d)

Fig 5(a) & 5(b): WL, PI Variation under RBI 81 and Sodium Silicate Fig. 5(c) & 5(d): UCS Variation under RBI 81 and Sodium Silicate

CONCLUSION

From the results we conclude that liquid limit decreases as the admixture content increases whereas its opposite in the case of plastic limit as it increases with increase in moisture content, results in reduction of plasticity index. Unconfined compressive strength increase with the increase in RBI 81 addition. It suggests us that it is a good stabilizer to improve performance of soft soils. Compared to RBI 81 the unconfined compressive strength values decreases with increase in the sodium silicate used as stabilizer.

5. **K. Suresh , V. Padmavathi , Apsar Sultana (Assistant Professor, CMR College of Engg & Tech., Hyderabad–501 401, India.)** carried out an experimental investigation to study the effect of stone dust and Polypropylene fibers on engineering and strength properties of the Black Cotton Soils. The properties of stabilized soil such as compaction characteristics, unconfined compressive strength and California bearing ratio were evaluated and their variations with content of stone dust and fibers are evaluated. Addition of either Optimum percentage of stone dust (3%) and Optimum Percentage of fibers (0.6%) or Optimum percentage of its combination to the Black Cotton Soil has improved the strength characteristics of sub grade .The soil used in the present study was collected from Shanker Pally, Medak District, Andhra Pradesh.

% SD	O.M.C %	γ_d gm/cc	q_u kg/cm^2	c kg/cm^2	C.B.R
0	24	1.495	5.847	2.92	1.02
1	21.6	1.475	7.34	3.67	2.5
2	22.8	1.482	7.63	3.81	2.70
3	23	1.531	9.36	4.68	2.91
4	22.3	1.537	8.703	4.35	2.49
5	16.5	1.56	6.34	3.71	2.08

Table 2. Effect of Stone Dust with Black Cotton Soil

%Fiber	O.M.C %	γ_d gm/cc	q_u kg/cm^2	Cu kg/cm^2	C.B.R
0	24	1.495	5.85	2.92	1.02
0.3	24	1.466	6.28	3.14	1.66
0.6	24	1.43	6.80	3.40	2.35
0.9	27	1.39	5.95	2.98	2.77
1.2	27	1.36	4.88	2.44	2.49

Table 3. Effect of Fiber with Black Cotton Soil

CONCLUSIONS

From the results we conclude that the best combination of soil and stone dust is found to be 3% of stone dust. The CBR values have shown improvement than the values of soil alone, the value is 1.574 times more than original value. For soil mixed with fibers only the best combination is found to be 0.6% of fibres. The CBR value is 1.27 times more than the original value. When the soil is mixed with both Stone dust and fibres, the proportion which yielded the maximum value were combined. The combination showed a significant increase the CBR value. The new value was 2.25 times the original value of soil alone. Also the values of unconfined compressive strength showed a significant increase.

CHAPTER 3: OBJECTIVES AND SCOPE

3.1 Objectives of the Project

1. To study different geotechnical properties of Black Cotton Soil that has been brought for the project. The various experiments will be performed in the Geotechical Laboratory of the University with the equipment provided. The geotechnical properties that will be studied includes
   - Moisture Content,
   - Specific Gravity,
   - Atterberg Limits,
   - Optimum Moisture Content,
   - Maximum Dry Density, and
   - Compressive Strength
2. To prepare Cubes of dimensions 100mm x 100mm x 100mm of Black Cotton Soil with different percentages of Lime and different layers of Geocomposites.
3. To study the change in compressive strength of Black Cotton Soil Cubes using different percentages (5%, 10% and 15%) of Lime.
4. To study the change in compressive strength of Black Cotton Soil Cubes using one layer of Geocomposite (with a composite of High-Density Polyethylene Geonet and Polypropylene Filter Geotextile) and different percentages of Lime.
5. To study the change in compressive strength of Black Cotton Soil Cubes using two layer of Geocomposite (with a composite of High-Density Polyethylene Geonet and Polypropylene Filter Geotextile) and 10% of Lime.
6. To recommend the most suitable composition of Lime and Geocomposite for a better stabilization based on the comparative study.

3.2 Scope of the Project

In this project we will perform laboratory tests on samples of black cotton soil. The tests will mainly include

3.2.1 **Water Content** – by Oven Drying Method

This test is done to determine the water content in soil by oven drying method as per IS: 2720 (Part II) – 1973. The water content (w) of a soil sample is equal to the mass of water divided by the mass of solids.

3.2.2 **Specific Gravity** – by use of Pycnometer

This test is done to determine the specific gravity of fine-grained soil by pycnometer method as per IS: 2720 (Part III/Sec 1) – 1980. Specific gravity is the ratio of the weight in air of a given volume of a material at a standard temperature to the weight in air of an equal volume of distilled water at the same stated temperature.

3.2.3 Atterberg Limits

Liquid Limit – by Casagrande Tool

This test is done to determine the liquid limit of soil as per IS: 2720 (Part 5) – 1985. The liquid limit of fine-grained soil is the water content at which soil behaves practically like a liquid, but has small shear strength. Its flow closes the groove in just 25 blows in Casagrande's liquid limit device.

Plastic Limit

This test is done to determine the plastic limit of soil as per IS: 2720 (Part 5) – 1985.The plastic limit of fine-grained soil is the water content of the soil below which it ceases to be plastic. It begins to crumble when rolled into threads of 3mm diameter.

After this, **we will classify the soil based on Indian Standard Soil Classification System and will plot its position on the Plasticity Chart.**

After this, we will perform-

3.2.4 Compaction Test

Light Compaction Test (Standard Proctor Test)

Compaction is the process of densification of soil by reducing air voids. The degree of compaction of a given soil is measured in terms of its dry density. The dry density is maximum at the optimum water content.

Compaction Curve for soil sample will be plotted between dry unit weight and water content.

3.2.5 Unconfined Compression Test

It is not always possible to conduct the bearing capacity test in the field. Sometimes it is cheaper to take the undisturbed soil sample and test its strength in the laboratory. Also one has to conduct strength tests on the samples selected. Under these conditions it is easy to perform the unconfined compression test on undisturbed and remoulded soil sample. We will investigate experimentally the strength of soil sample.

After performing the above mentioned tests on normal black cotton soil, we will perform compression test on cubes of black cotton soil by putting one layer of geocomposite in the center and two layers of geocomposites in the center, with various (5%, 10% and 15%) lime compositions present in black cotton soil.

CHAPTER 4: MATERIALS AND METHODOLOGY

4.1 Materials Required

4.1.1 Black Cotton Soil

The soil used in this project is a **Black Cotton Soil** collected from **Ramganj Mandi** in **Kota district, Rajasthan** in India. Ramganj Mandi is located at Latitude 24°38’50”N and Longitude 75°56’40”E. The community called the soil **‘Kali Mati’**.

The black cotton soil was collected by method of disturbed sampling after removing the top soil at 150mm depth and transported in sacks to the laboratory. The soil was air dried and sieved with IS sieve 4.75mm as required for laboratory test.

Fig 6(a). Black Cotton Soil **Fig 6(b). Lime**

4.1.2 Lime

In this project various percentage of Lime (i.e. 5%, 10%, and 15%) will be used as an admixture.

4.1.3 Geocomposite

Geocomposite used in this project has been bought from K.K. Enviro Tech. Pvt. Ltd., Kolkata which has a collaboration with a Spanish company Intermas Geosynthetics. Geocomposite is called **InterDRAIN GMG412**.

It is a **high-density polyethylene (HPDE) geonet** with two **polypropylene (PP) geotextiles** heat laminated. The geonet is made with 2 overcrossed strands at 60°, whose geometry creates channels with a high flow capacity, also under high pressures and at very low gradients.

The geocomposite reinforcement of size 100mm×100mm is placed at the middle of the cubical block i.e. at height of 50mm from bottom for one layer and at a height of 35mm and 70mm from bottom for two layer.

The **price of the geocomposite used was Rs.350/- per sq.m**. Various other properties of the geocomposite as provided by the supplier are -

Characteristics	Value	Unit	Standard
Geonet			
Polymer	High-Density Polyethylene(HDPE)		
Carbon Black	1.2-2.5	%	ASTM D 4218
Density	>0.94	g/cm^3	ASTM D 1505
Thickness at 2kPa/200kPa	4.2/3.8	mm	ISO 9863-1
Filter Geotextile			
Polymer	Polypropylene(PP)		
Mass per unit area	120	g/m^2	ISO 9864
CBR	1.4	kN	ISO 12236
Opening Size	<170	µm	ISO 12956
Drainage Geocomposite			
Mass per unit area	740	g/m^2	ISO 9864
Thickness at 2kPa/200kPa	4.8/4.2	mm	ISO 9863-1
Peak Tensile Strength	19	kN/m	ISO 10319
Elongation at break	40	%	ISO 10319

Table 4: The various properties of geocomposite taken from the catalog provided by the manufacturer.

Fig 7. Geocomposite InterDRAIN GMG412

4.1.4 Jute Bags

In this project, jute bag is used in the curing of the soil cubes. Each cube is wrapped in jute bags and water is then sprinkled on it.

4.2 Methodology

In this project we will perform laboratory tests on samples of black cotton soil. The tests will mainly include

4.2.1 Water Content – by Oven Drying Method

This test is done to determine the water content in soil by oven drying method as per IS: 2720 (Part II) – 1973. The water content (w) of a soil sample is equal to the mass of water divided by the mass of solids.

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This test is done to determine the liquid limit of soil as per IS: 2720 (Part 5) – 1985. The liquid limit of fine-grained soil is the water content at which soil behaves practically like a liquid, but has small shear strength. Its flow closes the groove in just 25 blows in Casagrande's liquid limit device.

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Light Compaction Test (Standard Proctor Test)

Compaction is the process of densification of soil by reducing air voids. The degree of compaction of a given soil is measured in terms of its dry density. The dry density is maximum at the optimum water content.

Compaction Curve for soil sample will be plotted between dry unit weight and water content.

4.2.5 Unconfined Compression Test

It is not always possible to conduct the bearing capacity test in the field. Sometimes it is cheaper to take the undisturbed soil sample and test its strength in the laboratory. Also one has to conduct strength tests on the samples selected. Under these conditions it is easy to perform the unconfined compression test on undisturbed and remoulded soil sample. We will investigate experimentally the strength of soil sample.

After performing the above mentioned tests on normal black cotton soil, we will perform compression test on cubes of black cotton soil by putting one layer of geocomposite in the center and two layers of geocomposites in the center, with various (5%, 10% and 15%) lime compositions present in black cotton soil.

CHAPTER 5: OBSERVATIONS AND RESULT

5.1 Moisture Content

Table 5: Moisture Content				
Determination Number	Units	1	2	3
Weight of Container, W_0	g	28.8	28.8	28.8
Weight of Container + Wet Soil, W_1	g	47.8	41	55.8
Weight of Container + Oven Dried Soil, W_2	g	46.5	40.2	54
Weight of Water, (W_1-W_2)	g	1.3	0.8	1.8
Weight of Oven dried Soil, (W_2-W_0)	g	17.7	11.4	25.2
Water Content, w	**%**	**7.34**	**7.02**	**7.14**

Moisture Content of Soil = Avg (7.34, 7.02, 7.14)
= 7.16%

5.2 Specific Gravity

Table 6: Specific Gravity		
Weight of Empty Pycnometer, W_1	g	464.5
Weight of Pycnometer + dry soil, W_2	g	662.6
Weight of Pycnometer + soil + water, W_3	g	1310
Weight of Pycnometer + water, W_4	g	1185
Specific Gravity, Gs		**2.71**

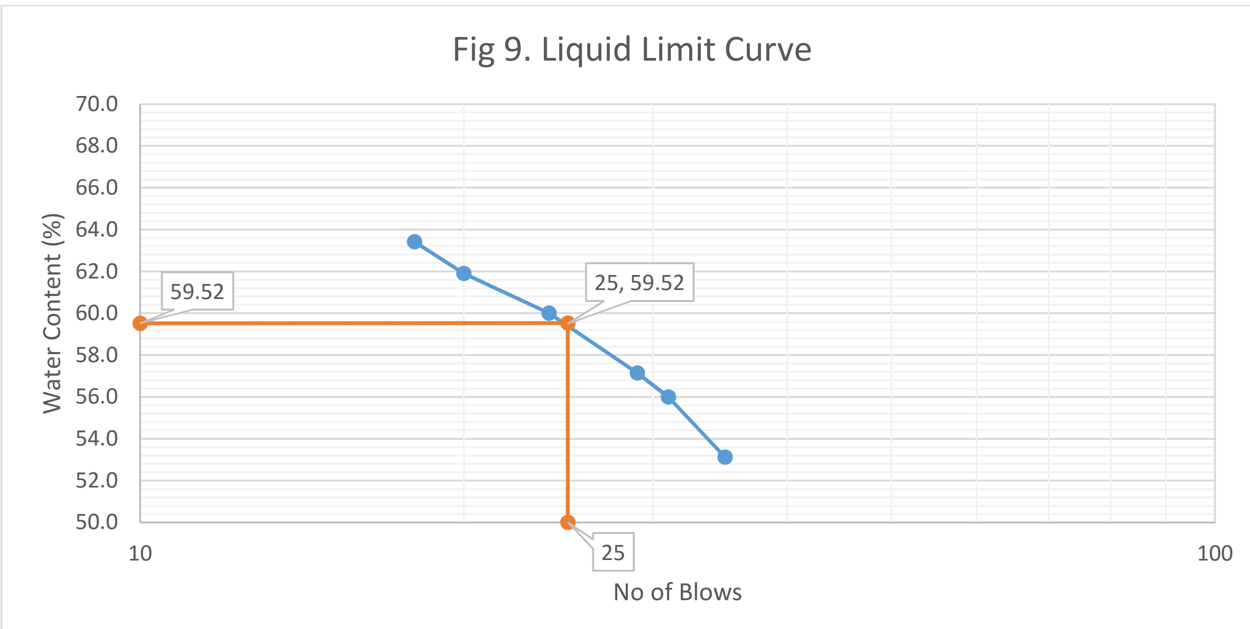
Fig 8. Taking weight during Specific Gravity Test

Table 7. Typical Values of Gs	
Clean Sands and Gravels	2.65-2.68
Silt and silty sands	2.66-2.70
Inorganic Clays	**2.70-2.80**
Soils high in mica, iron	2.75-2.85

These values are taken from the book 'Basic and Applied Soil Mechanics' by Gopal Ranjan & AS Rao.

5.3 Liquid Limit

Table 8: Liquid Limit							
Determination Number	Units	1	2	3	4	5	6
No. of Blows		18	20	24	29	31	35
Weight of Container, W_0	g	27.3	28.6	25.8	27.7	26.8	28.1
Weight of Container + Wet Soil, W_1	g	34	32	31.4	33.2	30.7	33
Weight of Container + Oven Dried Soil, W_2	g	31.4	30.7	29.3	31.2	29.3	31.3
Weight of Water, $(W_1\text{-}W_2)$	g	2.6	1.3	2.1	2	1.4	1.7
Weight of Oven dried Soil, $(W_2\text{-}W_0)$	g	4.1	2.1	3.5	3.5	2.5	3.2
Water Content, w	**%**	**63.4**	**61.90**	**60**	**57.14**	**56**	**53.13**



Liquid Limit of the soil from Fig.9 is equal to the water content at 25 number of blows, i.e. **59.52%.**

Atterberg's Limit	Recommended values as per IS 1498-1970
Liquid Limit	35-50%
Plastic Limit	Less than or equal to 40%
Plasticity Index	Greater than 10

Table 9. Recommended Values of Atterberg's Limits

Fig 10. Performing Liquid Limit Test

5.4 Plastic Limit

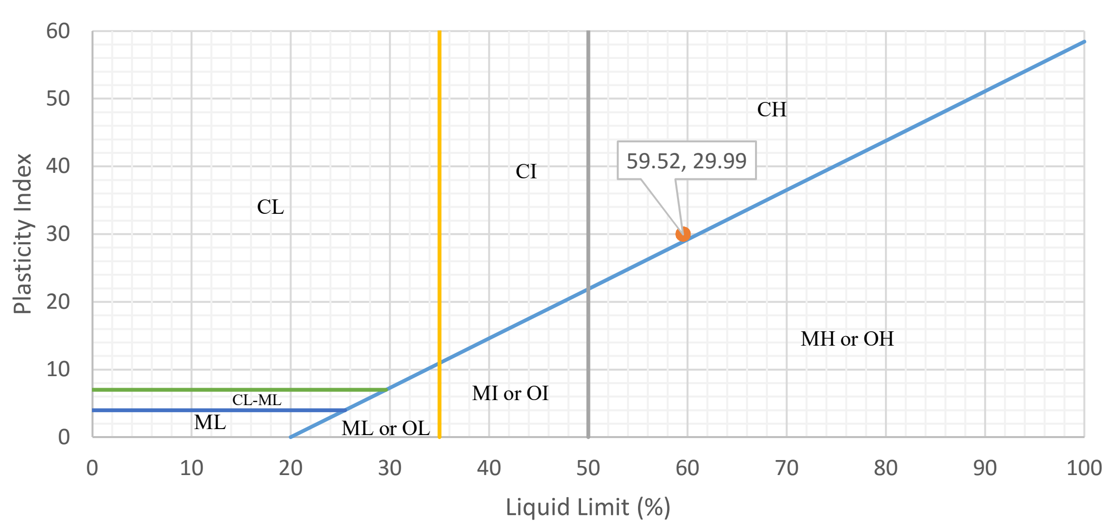
Table 10: Plastic Limit				
Determination Number	Units	1	2	3
Weight of Container, W_0	g	27.7	27.8	28.6
Weight of Container + Wet Soil, W_1	g	32.9	38.2	36.9
Weight of Container + Oven Dried Soil, W_2	g	31.8	35.8	34.9
Weight of Water, $(W_1\text{-}W_2)$	g	1.1	2.4	2
Weight of Oven dried Soil, $(W_2\text{-}W_0)$	g	4.1	8	6.3
Water Content, w	**%**	**26.83**	**30**	**31.75**

Plastic Limit = Avg (26.83, 30, 31.75)
= **29.53%**

Plasticity Index = Liquid Limit - Plastic Limit
= 59.52 - 29.53
= **29.99**

Plasticity chart has been taken from IS 1498-1970

Fig 11. Plasticity Chart

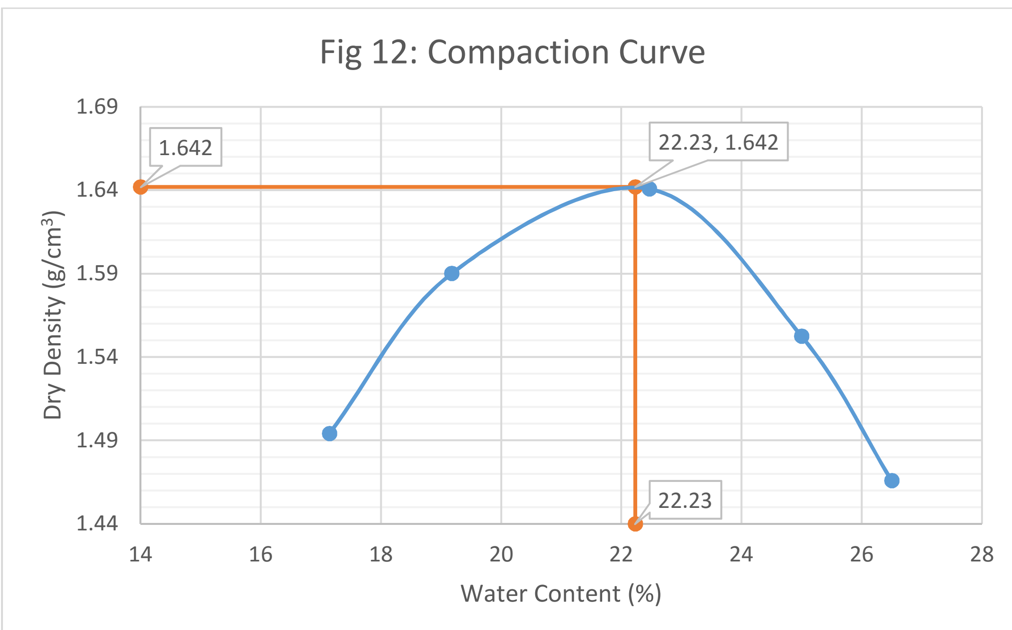


Since plasticity index is greater than 17, the soil **is highly plastic.**

Also from Fig.11, our soil is above A-Line in region CH**, its dry strength is high, toughness is high, and has no dilatency.**

5.5 Compaction Test (Light Compaction)

Table 11: Light Compaction						
Determination Number	Units	1	2	3	4	5
Volume of Mould, V	cm^3	1000	1000	1000	1000	1000
Weight of Mould, W_1	g	4320	4320	4320	4320	4320
Weight of mould + Compacted Soil, W_2	g	6070.3	6215	6329.4	6260.5	6174.4
Weight of compacted Soil, $W=(W_2-W_1)$	g	1750.3	1895	2009.4	1940.5	1854.4
Bulk Density, $\gamma_b=(W/V)$	g/cm^3	1.75	1.90	2.01	1.94	1.85
Weight of Container, W_0	g	29.3	27.8	28.8	29.3	28.2
Weight of Container + Wet Soil, W_1	g	41.6	45.2	45.7	46.8	53.5
Weight of Container + Oven Dried Soil, W_2	g	39.8	42.4	42.6	43.3	48.2
Weight of Water, (W_1-W_2)	g	1.8	2.8	3.1	3.5	5.3
Weight of Oven dried Soil, (W_2-W_0)	g	10.5	14.6	13.8	14	20
Water Content, w	%	17.14	19.18	22.46	25	26.5
Dry Density, $\gamma_d=(\gamma_b/(1+w))$	**g/cm^3**	**1.49**	**1.59**	**1.64**	**1.55**	**1.47**



The peak point of the compaction curve in Fig.12 corresponds to the maximum dry unit weight, $\gamma_{d(max)}$ which is equal **to 1.642 g/cm³**. The water content corresponding to the maximum dry unit weight is known as the optimum moisture content (OMC) which is equal **to 22.23%.**

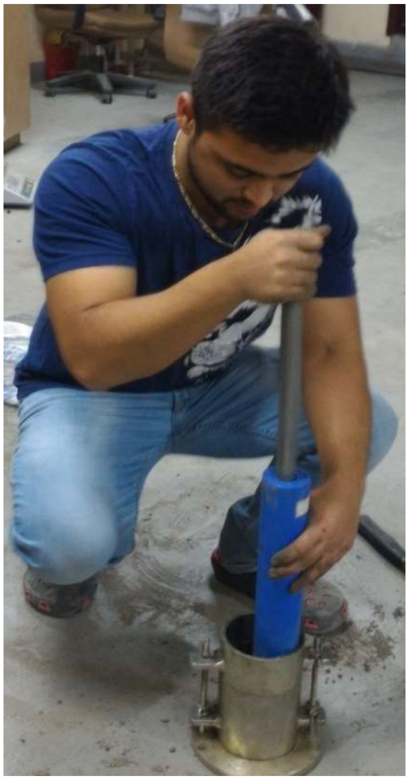


Fig 13. Performing Light Compaction

Fig 14. Triaxial/Unconfined Compressive Strength testing machine

Fig 15. Sample for Unconfined Compressive Strength

Fig 16. Setting zero in proving ring and dial gauge before experiment

5.6 Unconfined Compressive Strength (on cylindrical sample of 3.8cm diameter and 7.6 cm height)

Table 12: For Sample 1

Elapsed time (sec)	Compression dial reading	Compression dial reading(ΔL) Lc=0.01mm	Strain ε=(ΔL/L) (%)	Area Ac=Ao/(1-ε) (cm^2)	Proving Ring Reading	no of div	Axial Load, P (0.24kg/div)	Compressive stress, P/Ac (kg/cm^2)
0	0	0	0	11.34	0	0	0	0
20	25	0.25	0.033	11.726	0.6	3	0.72	0.614
40	30	0.3	0.039	11.806	1	5	1.2	1.016
60	60	0.6	0.079	12.312	1.6	8	1.92	1.559
80	77	0.77	0.101	12.618	1.6	8	1.92	1.522
100	103	1.03	0.136	13.118	1.8	9	2.16	1.647
120	117	1.17	0.154	13.403	1.8	9	2.16	1.612
140	105	1.05	0.138	13.158	1.8	9	2.16	1.642
160	90	0.9	0.118	12.863	1.8	9	2.16	1.679
180	95	0.95	0.125	12.960	2	10	2.4	1.852
200	125	1.25	0.164	13.572	2.2	11	2.64	1.945
220	155	1.55	0.204	14.245	2.4	12	2.88	2.022
240	180	1.8	0.237	14.859	2.4	12	2.88	1.938
260	215	2.15	0.283	15.814	2.4	12	2.88	1.821
280	245	2.45	0.322	16.735	2.2	11	2.64	1.578
300	255	2.55	0.336	17.066	1.8	9	2.16	1.266
320	260	2.6	0.342	17.237	1.6	8	1.92	1.114

Table 13: For Sample 2

Elapsed time (sec)	Compression dial reading	Compression dial reading(ΔL) Lc=0.01mm	Strain ε=(ΔL/L) (%)	Area Ac=Ao/(1-ε) (cm^2)	Proving Ring Reading	no of div	Axial Load, P (0.24kg/div)	Compressive stress, P/Ac (kg/cm^2)
0	0	0	0.000	11.340	0	0	0	0.000
20	18	0.18	0.024	11.615	1.2	6	1.44	1.240
40	54	0.54	0.071	12.207	2.2	11	2.64	2.163
60	90	0.9	0.118	12.863	2.6	13	3.12	2.426
80	115	1.15	0.151	13.362	2.8	14	3.36	2.515
100	140	1.4	0.184	13.901	2.8	14	3.36	2.417
120	135	1.35	0.178	13.789	2.8	14	3.36	2.437
140	158	1.58	0.208	14.316	3	15	3.6	2.515
160	184	1.84	0.242	14.963	3	15	3.6	2.406
180	205	2.05	0.270	15.529	3.2	16	3.84	2.473
200	232	2.32	0.305	16.323	3.2	16	3.84	2.353
220	258	2.58	0.339	17.168	3.4	17	4.08	2.376
240	292	2.92	0.384	18.415	3.6	18	4.32	2.346
260	335	3.35	0.441	20.279	3.8	19	4.56	2.249

Table 14: For Sample 3

Elapsed time (sec)	Compression dial reading	Compression dial reading(ΔL) Lc=0.01mm	Strain ε=(ΔL/L) (%)	Area Ac=Ao/(1-ε) (cm2)	Proving Ring Reading	no of div	Axial Load, P (0.24kg/div)	Compressive stress, P/Ac (kg/cm2)
0	0	0	0.000	11.340	0	0	0	0.000
20	15	0.15	0.020	11.568	0.8	4	0.96	0.830
40	15	0.15	0.020	11.568	0.8	4	0.96	0.830
60	35	0.35	0.046	11.887	0.8	4	0.96	0.808
80	45	0.45	0.059	12.054	1	5	1.2	0.996
100	60	0.6	0.079	12.312	1.2	6	1.44	1.170
120	90	0.9	0.118	12.863	1.6	8	1.92	1.493
140	95	0.95	0.125	12.960	1.6	8	1.92	1.481
160	80	0.8	0.105	12.674	1.4	7	1.68	1.326
180	95	0.95	0.125	12.960	1.8	9	2.16	1.667
200	110	1.1	0.145	13.259	1.8	9	2.16	1.629
220	140	1.4	0.184	13.901	2	10	2.4	1.727
240	175	1.75	0.230	14.732	2	10	2.4	1.629
260	210	2.1	0.276	15.670	2	10	2.4	1.532
280	225	2.25	0.296	16.109	2.2	11	2.64	1.639
300	245	2.45	0.322	16.735	2.2	11	2.64	1.578
320	265	2.65	0.349	17.411	2.2	11	2.64	1.516
340	275	2.75	0.362	17.770	2	10	2.4	1.351
360	280	2.8	0.368	17.955	1.8	9	2.16	1.203

From table 12, 13 and 14 above, readings of three different samples are found. The Unconfined Compressive Strength of the Soil is the peak point of the stress-strain curve which is shown in Fig 17, 18 and 19. From the curves, The value for sample 1 is **2.022 kg/cm^2**

The value for sample 2 is **2.515 kg/cm^2**

The value for sample 3 is **1.727 kg/cm^2**

So, taking average of the readings, the **unconfined compressive strength of the soil is 2.088 kg/cm^2**

So, the shear strength of the soil is**, c = (q_u/2) = 1.044 kg/cm^2**

Since the value of unconfined compressive strength is between 2-4 kg/cm^2, the soil used is very stiff in terms of consistency.

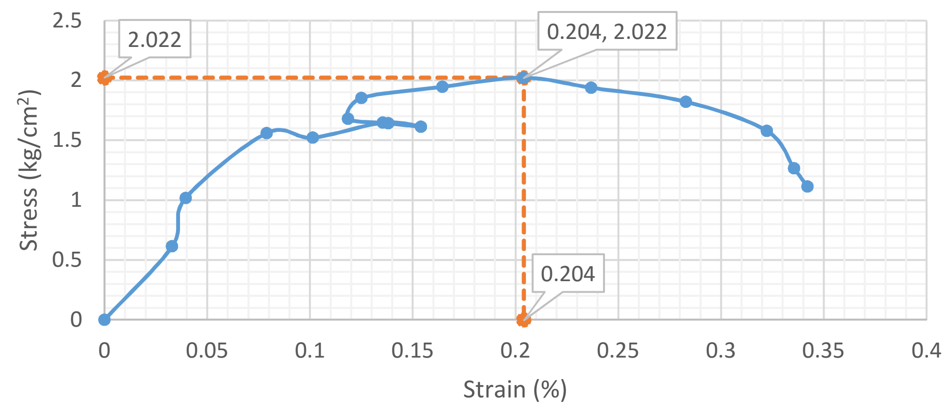


Fig 17. Unconfined Compressive Strength for Cylindrical Sample 1

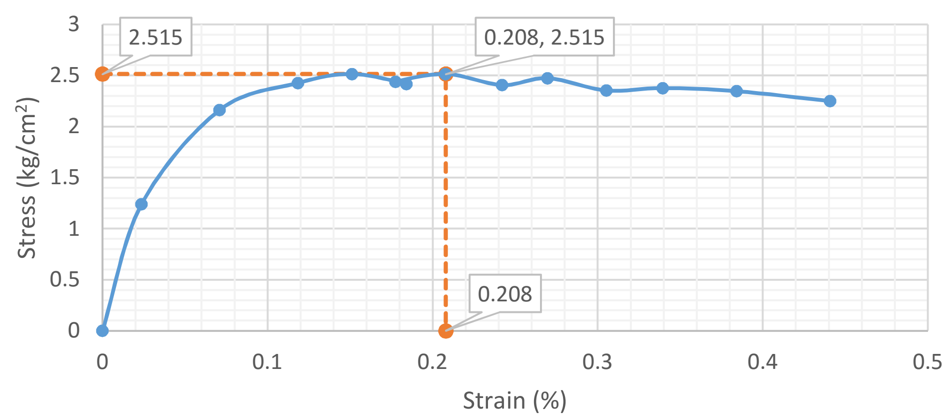


Fig 18.Unconfined Compressive Strength for Cylindrical Sample 2

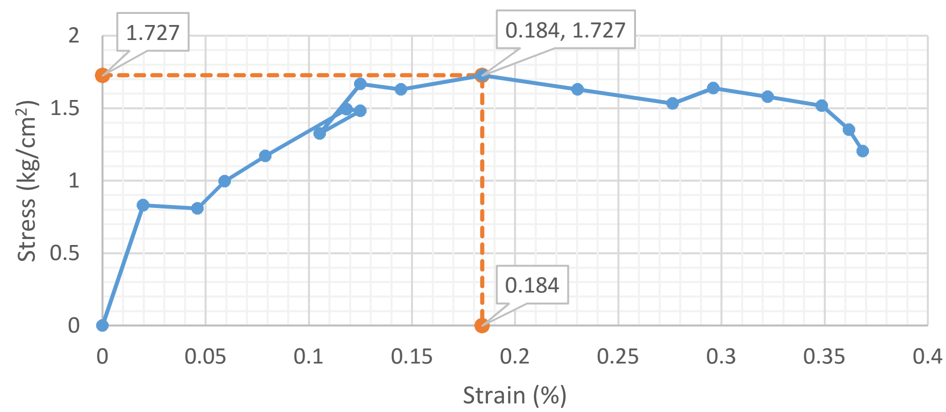


Fig 19. Unconfined Compressive Strength for Cylindrical Sample 3

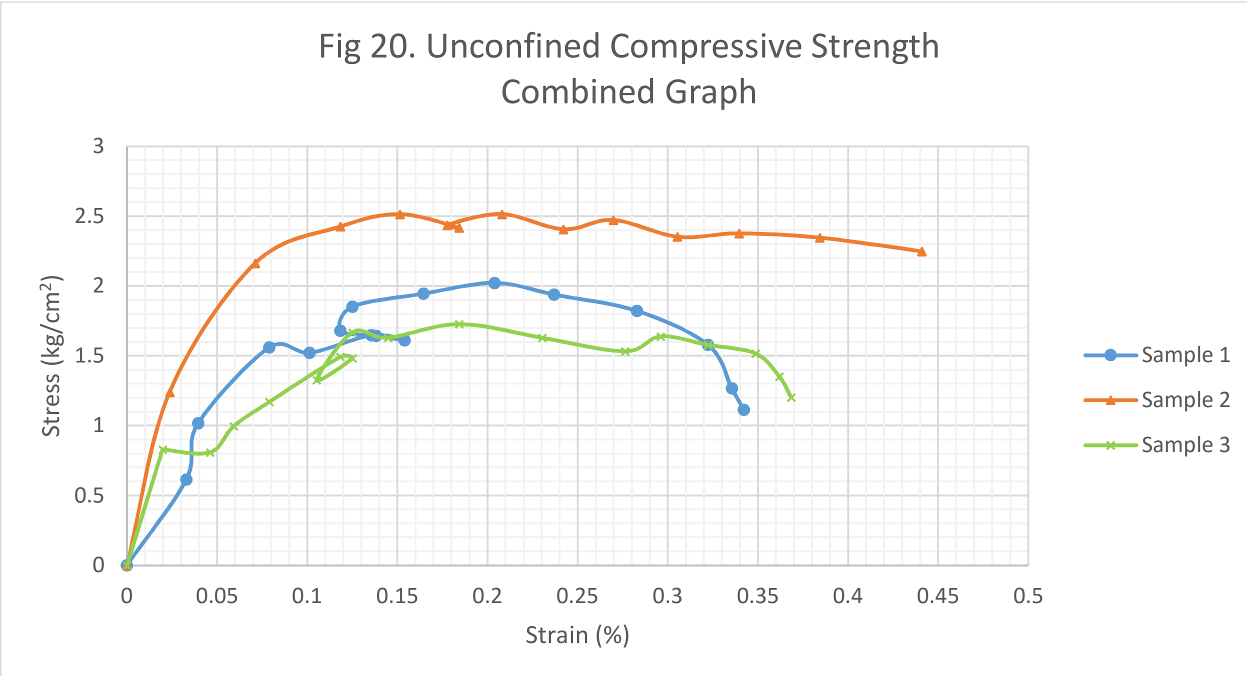


Fig 21. Deflection pattern in sample during the test

Fig 22. Cracks developed in sample after the test

Fig 23. Pic of a freshly prepared sample and the deformed sample placed side by side

5.7 Unconfined Compressive Strength (on cubical sample of side 10cm)

Table 15: For Sample 1

Elapsed time (sec)	Compression dial reading	Compression dial reading(ΔL) Lc=0.01mm	Strain ε=(ΔL/L) (%)	Area Ac=Ao/(1-ε) (cm^2)	Proving Ring Reading	no of div	Axial Load, P (0.24kg/div)	Compressive stress, P/Ac (kg/cm^2)
0	0	0	0	100	0	0	0	0
20	40	0.4	0.4	100.402	8.2	41	9.84	0.980
40	80	0.8	0.8	100.806	16.4	82	19.68	1.952
60	120	1.2	1.2	101.215	22.4	112	26.88	2.656
80	165	1.65	1.65	101.678	28.8	144	34.56	3.399
100	210	2.1	2.1	102.145	34.6	173	41.52	4.065
120	260	2.6	2.6	102.669	39.8	199	47.76	4.652
140	290	2.9	2.9	102.987	43.8	219	52.56	5.104
160	332	3.32	3.32	103.434	47	235	56.4	5.453
180	370	3.7	3.7	103.842	50.2	251	60.24	5.801
200	405	4.05	4.05	104.221	52.6	263	63.12	6.056
220	450	4.5	4.5	104.712	54.6	273	65.52	6.257
240	495	4.95	4.95	105.208	56.6	283	67.92	6.456
260	545	5.45	5.45	105.764	57.8	289	69.36	6.558
280	580	5.8	5.8	106.157	59.2	296	71.04	6.692
300	620	6.2	6.2	106.610	60.2	301	72.24	6.776
320	680	6.8	6.8	107.296	61.4	307	73.68	6.867
340	735	7.35	7.35	107.933	63.2	316	75.84	7.027
360	780	7.8	7.8	108.460	64	320	76.8	7.081
380	825	8.25	8.25	108.992	65	325	78	7.157
400	875	8.75	8.75	109.589	65.6	328	78.72	7.183
420	910	9.1	9.1	110.011	66	330	79.2	7.199
440	950	9.5	9.5	110.497	66.8	334	80.16	7.254
460	995	9.95	9.95	111.049	67.4	337	80.88	7.283
480	1040	10.4	10.4	111.607	68	340	81.6	7.311
500	1075	10.75	10.75	112.045	68.4	342	82.08	7.326
520	1115	11.15	11.15	112.549	69	345	82.8	7.357
540	1160	11.6	11.6	113.122	69.4	347	83.28	7.362
560	1210	12.1	12.1	113.766	70	350	84	7.384
580	1240	12.4	12.4	114.155	70.4	352	84.48	7.400
600	1280	12.8	12.8	114.679	71	355	85.2	7.429
620	1320	13.2	13.2	115.207	71.6	358	85.92	7.458
640	1370	13.7	13.7	115.875	72	360	86.4	7.456
660	1400	14	14	116.279	72.2	361	86.64	7.451
680	1445	14.45	14.45	116.891	73	365	87.6	7.494

700	1500	15	15	117.647	73.2	366	87.84	7.466
720	1540	15.4	15.4	118.203	73.4	367	88.08	7.452
740	1570	15.7	15.7	118.624	73.8	369	88.56	7.466
760	1615	16.15	16.15	119.261	74.2	371	89.04	7.466
780	1650	16.5	16.5	119.760	74.6	373	89.52	7.475
800	1690	16.9	16.9	120.337	74.8	374	89.76	7.459
820	1735	17.35	17.35	120.992	75.2	376	90.24	7.458
840	1780	17.8	17.8	121.655	75.4	377	90.48	7.437
860	1830	18.3	18.3	122.399	75.8	379	90.96	7.431
880	1865	18.65	18.65	122.926	76	380	91.2	7.419

Table 16: For Sample 2

Elapsed time (sec)	Compression dial reading	Compression dial reading(ΔL) Lc=0.01mm	Strain ε=(ΔL/L) (%)	Area Ac=Ao/(1-ε) (cm^2)	Proving Ring Reading	no of div	Axial Load, P (0.24kg/div)	Compressive stress, P/Ac (kg/cm^2)
0	0	0	0	100.000	0	0	0	0.000
20	35	0.35	0.35	100.351	5.2	26	6.24	0.622
40	80	0.8	0.8	100.806	11.6	58	13.92	1.381
60	120	1.2	1.2	101.215	16.2	81	19.44	1.921
80	160	1.6	1.6	101.626	20.6	103	24.72	2.432
100	210	2.1	2.1	102.145	24.8	124	29.76	2.914
120	255	2.55	2.55	102.617	28.8	144	34.56	3.368
140	305	3.05	3.05	103.146	32.8	164	39.36	3.816
160	330	3.3	3.3	103.413	35.6	178	42.72	4.131
180	370	3.7	3.7	103.842	37.8	189	45.36	4.368
200	410	4.1	4.1	104.275	40.2	201	48.24	4.626
220	450	4.5	4.5	104.712	42	210	50.4	4.813
240	500	5	5	105.263	43.4	217	52.08	4.948
260	545	5.45	5.45	105.764	45	225	54	5.106
280	640	6.4	6.4	106.838	47.4	237	56.88	5.324
300	670	6.7	6.7	107.181	48.6	243	58.32	5.441
320	710	7.1	7.1	107.643	49.4	247	59.28	5.507
340	745	7.45	7.45	108.050	50.2	251	60.24	5.575
360	780	7.8	7.8	108.460	51	255	61.2	5.643
380	830	8.3	8.3	109.051	51.8	259	62.16	5.700
400	880	8.8	8.8	109.649	52.4	262	62.88	5.735
420	920	9.2	9.2	110.132	53.4	267	64.08	5.818
440	955	9.55	9.55	110.558	54	270	64.8	5.861
460	995	9.95	9.95	111.049	54.8	274	65.76	5.922
480	1035	10.35	10.35	111.545	55.6	278	66.72	5.981
500	1080	10.8	10.8	112.108	56.2	281	67.44	6.016

520	1120	11.2	11.2	112.613	56.6	283	67.92	6.031
540	1165	11.65	11.65	113.186	57.4	287	68.88	6.086
560	1205	12.05	12.05	113.701	57.8	289	69.36	6.100
580	1245	12.45	12.45	114.220	58.4	292	70.08	6.136
600	1280	12.8	12.8	114.679	59.2	296	71.04	6.195
620	1330	13.3	13.3	115.340	59.4	297	71.28	6.180
640	1365	13.65	13.65	115.808	60.2	301	72.24	6.238
660	1415	14.15	14.15	116.482	60.6	303	72.72	6.243
680	1455	14.55	14.55	117.028	60.8	304	72.96	6.234
700	1495	14.95	14.95	117.578	61.6	308	73.92	6.287
720	1535	15.35	15.35	118.133	62.2	311	74.64	6.318
740	1570	15.7	15.7	118.624	62.8	314	75.36	6.353
760	1610	16.1	16.1	119.190	63.2	316	75.84	6.363
780	1660	16.6	16.6	119.904	63.4	317	76.08	6.345
800	1705	17.05	17.05	120.555	64	320	76.8	6.371
820	1750	17.5	17.5	121.212	64.2	321	77.04	6.356
840	1790	17.9	17.9	121.803	64.6	323	77.52	6.364
860	1830	18.3	18.3	122.399	65	325	78	6.373
880	1865	18.65	18.65	122.926	65.2	326	78.24	6.365

Table 17: For Sample 3

Elapsed time (sec)	Compression dial reading	Compression dial reading(ΔL) Lc=0.01mm	Strain ε=(ΔL/L) (%)	Area Ac=Ao/(1-ε) (cm2)	Proving Ring Reading	no of div	Axial Load, P (0.24kg/div)	Compressive stress, P/Ac (kg/cm2)
0	0	0	0	100.000	0	0	0	0.000
20	43	0.43	0.43	100.432	7.2	36	8.64	0.860
40	85	0.85	0.85	100.857	13.4	67	16.08	1.594
60	130	1.3	1.3	101.317	19.2	96	23.04	2.274
80	176	1.76	1.76	101.792	25.6	128	30.72	3.018
100	250	2.5	2.5	102.564	35	175	42	4.095
120	295	2.95	2.95	103.040	39.6	198	47.52	4.612
140	340	3.4	3.4	103.520	44	220	52.8	5.100
160	375	3.75	3.75	103.896	46.4	232	55.68	5.359
180	415	4.15	4.15	104.330	48.6	243	58.32	5.590
200	465	4.65	4.65	104.877	50.6	253	60.72	5.790
220	510	5.1	5.1	105.374	52.6	263	63.12	5.990
240	550	5.5	5.5	105.820	54.2	271	65.04	6.146
260	585	5.85	5.85	106.213	55.4	277	66.48	6.259
280	625	6.25	6.25	106.667	56.6	283	67.92	6.368
300	700	7	7	107.527	58.4	292	70.08	6.517
320	750	7.5	7.5	108.108	59.4	297	71.28	6.593

340	795	7.95	7.95	108.637	60.2	301	72.24	6.650
360	840	8.4	8.4	109.170	60.8	304	72.96	6.683
380	875	8.75	8.75	109.589	61.6	308	73.92	6.745
400	915	9.15	9.15	110.072	62	310	74.4	6.759
420	950	9.5	9.5	110.497	63	315	75.6	6.842
440	990	9.9	9.9	110.988	63.6	318	76.32	6.876
460	1035	10.35	10.35	111.545	64	320	76.8	6.885
480	1085	10.85	10.85	112.170	64.4	322	77.28	6.890
500	1140	11.4	11.4	112.867	65.2	326	78.24	6.932
520	1170	11.7	11.7	113.250	65.4	327	78.48	6.930
540	1205	12.05	12.05	113.701	66	330	79.2	6.966
560	1250	12.5	12.5	114.286	66.6	333	79.92	6.993
580	1285	12.85	12.85	114.745	67.2	336	80.64	7.028
600	1325	13.25	13.25	115.274	67.4	337	80.88	7.016
620	1370	13.7	13.7	115.875	67.8	339	81.36	7.021
640	1415	14.15	14.15	116.482	68.2	341	81.84	7.026
660	1460	14.6	14.6	117.096	68.4	342	82.08	7.010
680	1500	15	15	117.647	68.8	344	82.56	7.018
700	1535	15.35	15.35	118.133	69.2	346	83.04	7.029
720	1575	15.75	15.75	118.694	69.8	349	83.76	7.057
740	1615	16.15	16.15	119.261	70.2	351	84.24	7.064
760	1655	16.55	16.55	119.832	70.4	352	84.48	7.050
780	1705	17.05	17.05	120.555	71.2	356	85.44	7.087
800	1750	17.5	17.5	121.212	71.4	357	85.68	7.069
820	1795	17.95	17.95	121.877	71.8	359	86.16	7.069
840	1830	18.3	18.3	122.399	72	360	86.4	7.059
860	1870	18.7	18.7	123.001	72.4	362	86.88	7.063

Also graph for each sample is plotted and shown in Fig. 24, 25 and 26 and compressive strength of the cube is calculated. From the readings obtained from Table 15, 16 and 17 of three different samples, the Unconfined Compressive Strength of the Soil is the peak point of the stress-strain curve. From the curves, The value for sample 1 is **7.494 kg/cm^2**

The value for sample 2 is **6.373 kg/cm^2**

The value for sample 3 is **7.087 kg/cm^2**

So taking average of the readings,

The **unconfined compressive strength of the cube is 6.985 kg/cm^2**

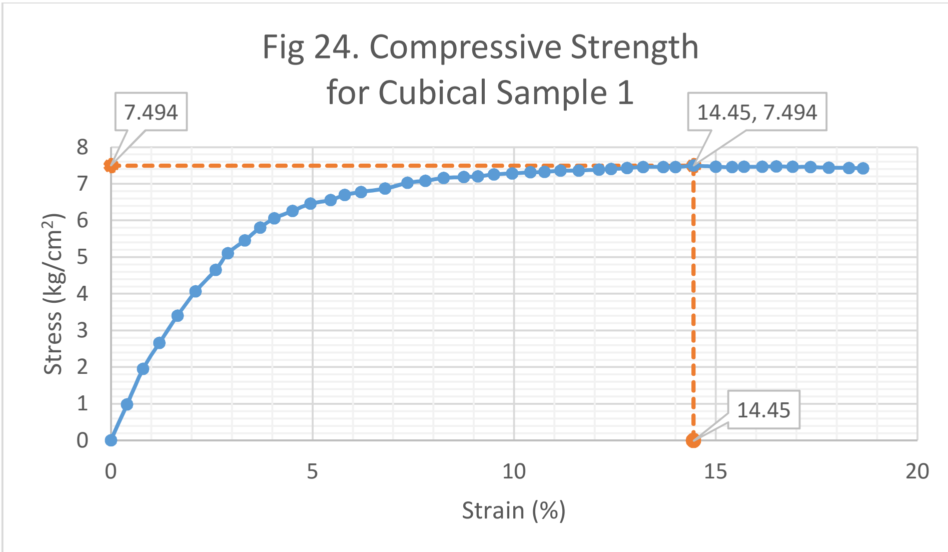


Fig 24. Compressive Strength for Cubical Sample 1

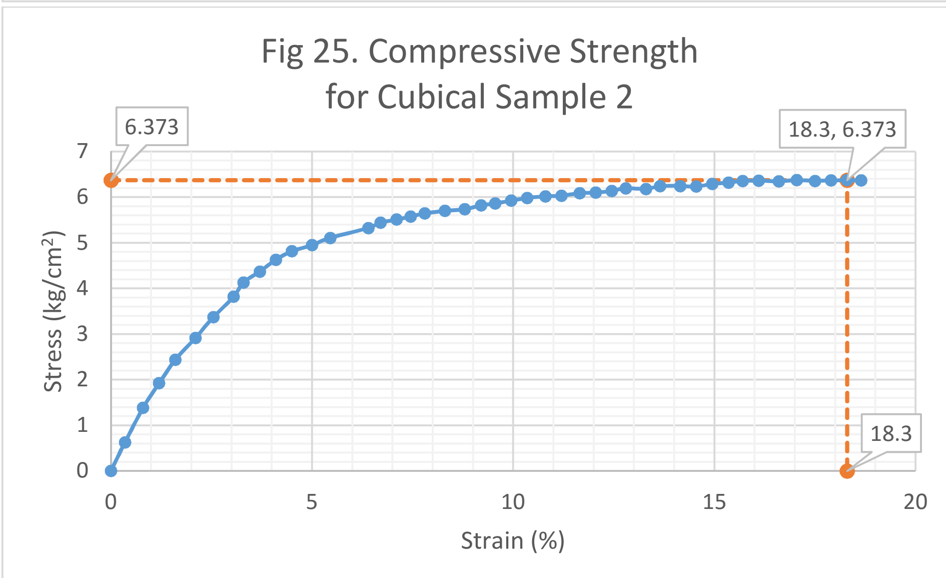


Fig 25. Compressive Strength for Cubical Sample 2

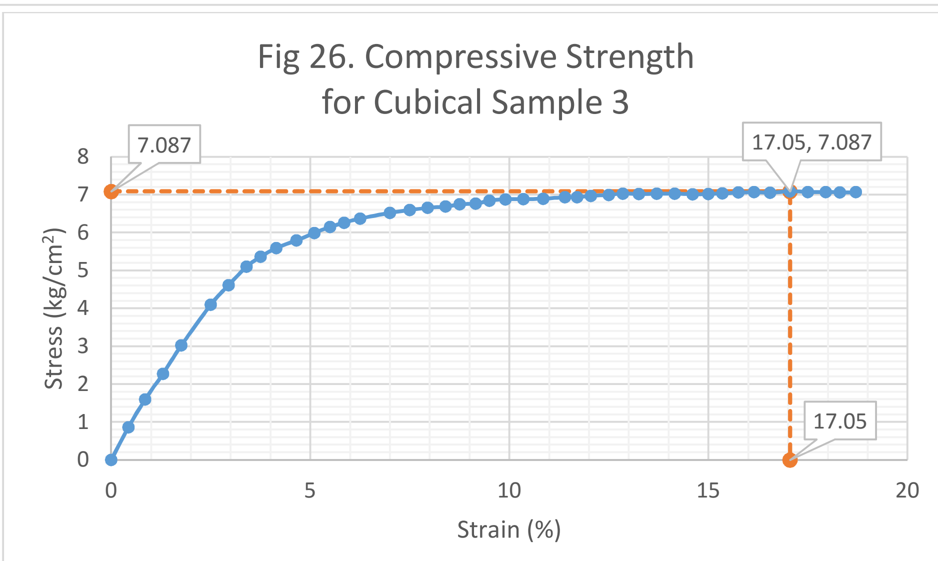


Fig 26. Compressive Strength for Cubical Sample 3

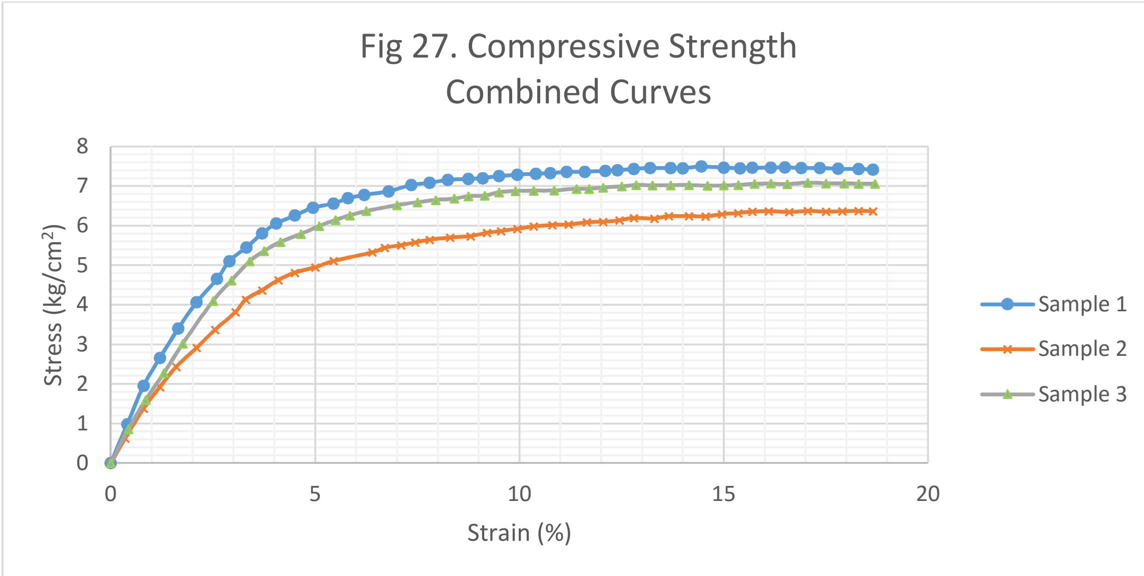


Fig 28. Performing compressive strength on soil cube

Fig 29. Front view of the deformed cubes

Fig 30. Cracks developed on cube during the test

5.8 Compression test on Black Cotton soil and Lime cubes without Geocomposite reinforcement

Table 18: 3 Days Curing

Lime %	Reading (in kN)	Compressive Strength (kg/cm^2)
5	11	11.2
10	17	17.3
15	20	20.4

Table 19: 7 Days Curing

Lime %	Reading (in kN)	Compressive Strength (kg/cm^2)
5	10	10.2
10	20	20.4
15	25	25.5

Table 20: 14 Days Curing

Lime %	Reading (in kN)	Compressive Strength (kg/cm^2)
5	9	9.2
10	18	18.3
15	36	36.7

Table 21: 28 Days Curing

Lime %	Reading (in kN)	Compressive Strength (kg/cm^2)
5	15	15.3
10	19	19.4
15	32	32.6

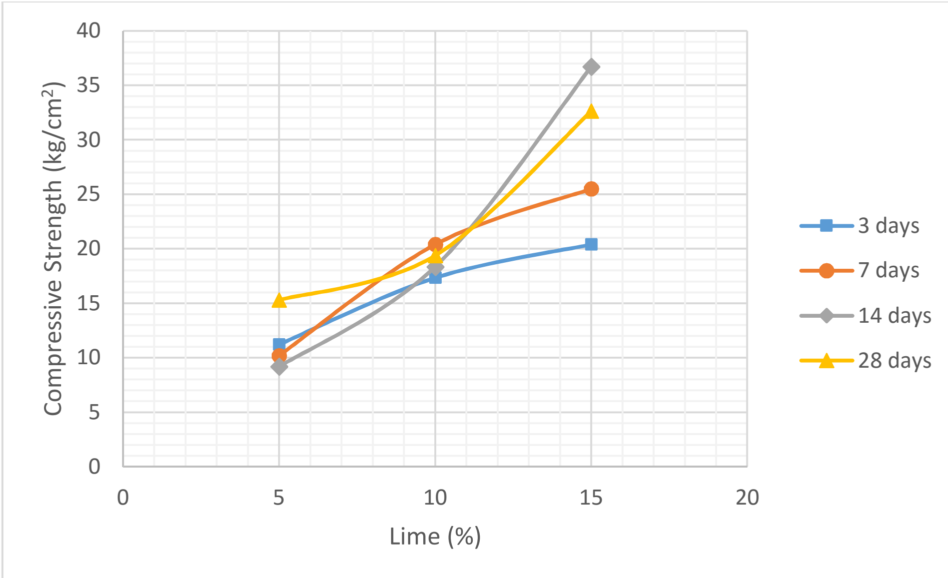


Fig 31: Variation of Compressive Strength of Black Cotton soil cubes without Geocomposite reinforcement

Fig 31. shows variation of compressive strength of Black Cotton soil cubes without Geocomposite reinforcement for various days of curing period. **The graph is plotted against Compressive Strength of Black Cotton soil cubes without Geocomposite reinforcement and % of Lime.** From fig, it is observed that

1. The compressive strength of the rectangular Black Cotton soil blocks without geocomposite reinforcement for 5% lime content and 3, 7, 14 and 28 days curing period is 11.2, 10.2, 9.2 and 15.3 kg/cm^2 whereas for 10% and 15% lime is (i) 17.3, 20.4, 18.3 and 19.4 kg/cm^2 (ii) 20.4, 25.5, 36.7 and 32.6 kg/cm^2 respectively.
2. For 15% lime content, the maximum compressive strength of the Black Cotton soil block is observed as 20.2, 25.5, 36.7 and 32.6 kg/cm^2 for 3, 7, 14 and 28 days curing period. The optimum lime content for the Black Cotton soil block is 15%.
3. The maximum value of Compressive Strength is given by Black Cotton soil blocks with addition of 15% lime after 14 days of curing and the value is 36.7 kg/cm^2.

Fig 32. Black Cotton Soil Cube with lime but without geocomposite reinforcement

Fig 33. Breaking pattern of Soil cube without geocomposite reinforcement

5.9 Compression test on Black Cotton soil and Lime Cubes with one layer of Geocomposite reinforcement

Fig 34. Placing one layer of geocomposite inside the mould during cube formation

Table 22: 3 Days Curing

Lime %	Reading (in kN)	Compressive Strength (kg/cm^2)
5	13	13.3
10	30	30.6
15	43	43.8

Table 23: 7 Days Curing

Lime %	Reading (in kN)	Compressive Strength (kg/cm^2)
5	14	14.3
10	36	36.7
15	40	40.8

Table 24: 14 Days Curing

Lime %	Reading (in kN)	Compressive Strength (kg/cm^2)
5	17	17.3
10	32	32.6
15	60	61.2

Table 25: 28 Days Curing

Lime %	Reading (in kN)	Compressive Strength (kg/cm^2)
5	32	32.6
10	38	38.7
15	72	73.2

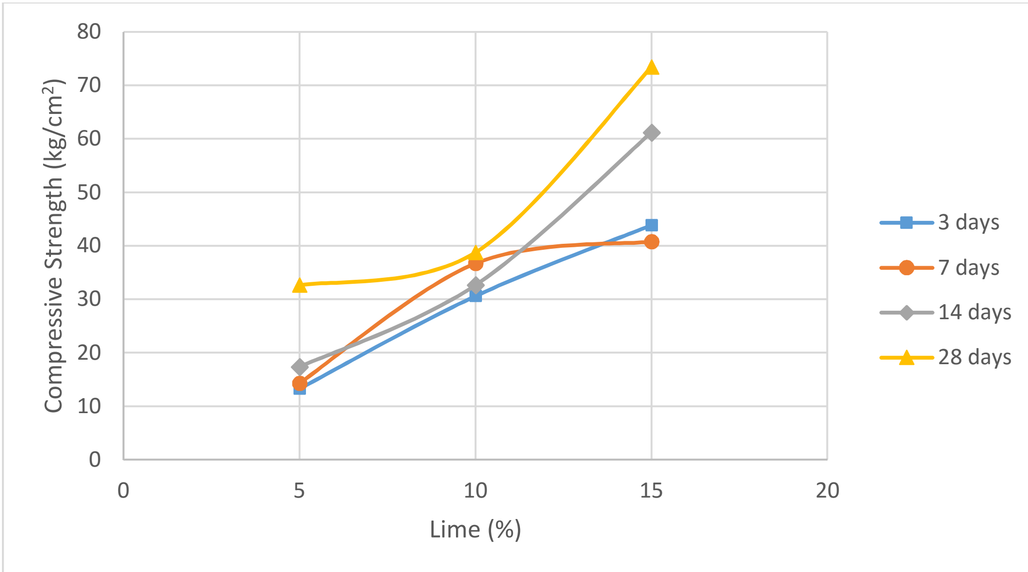


Fig. 35: Variation of Compressive Strength of Black Cotton soil cubes with one layer of Geocomposite reinforcement

Fig 35. Shows variation of compressive strength of Black Cotton soil cubes with one layer of Geocomposite reinforcement for various days of curing period. **The graph is plotted against Compressive Strength of Black Cotton soil cubes with Geocomposite reinforcement and % of Lime.** From Fig it is observed that,

1. The compressive strength of the rectangular Black Cotton soil blocks with one layer of geocomposite reinforcement for 5% lime content and 3, 7, 14 and 28 days curing period is 13.2, 14.3, 17.3 and 32.6 kg/cm^2 whereas for 10% and 15% lime is (i) 30.6, 36.7, 32.6 and 38.7 kg/cm^2 (ii) 43.8, 40.8, 61.2 and 73.4 kg/cm^2 respectively.
2. For 15% lime content, the maximum compressive strength of the Black Cotton soil block is observed as 43.8, 40.8, 61.2 and 73.4 kg/cm^2 for 3, 7, 14 and 28 days curing period. The optimum lime content for the Black Cotton soil block is 15%.
3. The maximum value of Compressive Strength is given by Black Cotton soil blocks with addition of 15% lime after 28 days of curing and the value is 73.4 kg/cm^2.

Fig 36. Black Cotton Soil cube with one layer of geocomposite reinforcement placed on compression testing machine

Fig 37. Breaking pattern of soil cube with one layer of geocomposite reinforcement

5.10 Compression Test on Black Cotton Soil and Lime Blocks with double layer of Geocomposite

Fig 38. Placing first layer of geocomposite inside the mould

Fig 39. Placing Second layer of geocomposite inside the mould

Figure 40 shows variation of compressive strength of Black Cotton Soil blocks with double layer of geocomposite reinforcement for various days of curing period for 10% lime content. The graph was plotted against compressive strength of black cotton soil blocks with geocomposite reinforcement and the days of curing period.

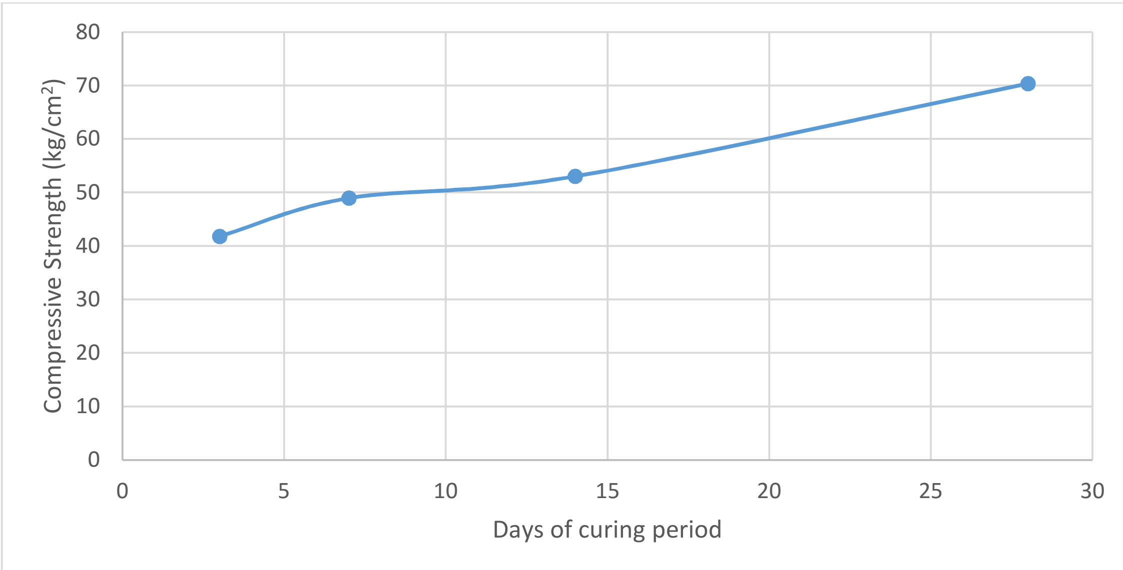


Fig. 40. Variation of Compressive Strength of Black Cotton Soil blocks with two layer of Geocomposite reinforcement

From Figure 40 it is observed that, the maximum value of Compressive Strength is given by Black Cotton soil blocks after 28 days of curing and the value is 70.3 kg/cm^2.

Fig 41. Breaking Pattern of Soil Cube with two layer of geocomposite reinforcement

CHAPTER 6: CONCLUSION AND DISCUSSION

6.1 General Conclusions

From the results we conclude that the specific gravity of the soil used is well within the limits as prescribed by IS1498-1970. The liquid limit of the soil came out to be 59.52% which is slightly above the prescribed limits by IS1498-1970 which suggests that the soil is highly compressible and traces of hydrated Halloysite and Nontronite may be present. The plastic limit of 29.53% is well within the prescribed values by IS1498-1970 and suggests that traces of Nontronite may be present. The plasticity index of 29.99 i.e. 30 indicates that the soil is highly plastic. The position of the soil is above A-Line in the Plasticity Chart which means the soil is classified as CH i.e. clay with high liquid limit. The optimum moisture content of the soil is 22.23% which is well within the prescribed limits by IS1498-1970. The maximum dry unit weight of the soil is 1.642 g/cm^3 is well within the prescribed limit by IS1498-1970.

The unconfined compressive strength of the soil came out to be 2.088 kg/cm^2 which suggests that the clay is very stiff. The compressive strength of cube of Black Cotton Soil came out to be 6.985 kg/cm^2 which was found to be higher than the value for the cylindrical sample.

Lime and geocomposite is used as reinforcement for improving the geotechnical characteristics of black cotton soils. Lime significantly improves strength characteristics of black cotton soil under study and the effect of lime vary depending upon the quantity of lime that is mixed with the black cotton soil sample.

The compressive strength of these soils increases upon the addition of lime. The trend of improvement in the compressive strength is observed to be more pronounced with the curing of the soil and lime mix. A curing period of 28 days is observed to yield the maximum compressive strength of Black Cotton soil blocks reinforced with 15% lime content and geocomposite.
A curing period of 14 days is observed to yield the maximum enhancement in the compressive strength of Black Cotton soil blocks for addition of 15% lime content and geocomposite reinforcement with respect to addition of 5% lime content.

6.2 Comparison of percentage increase in Compressive Strength with respect to 5% Lime content

6.2.1 For 3 days curing period

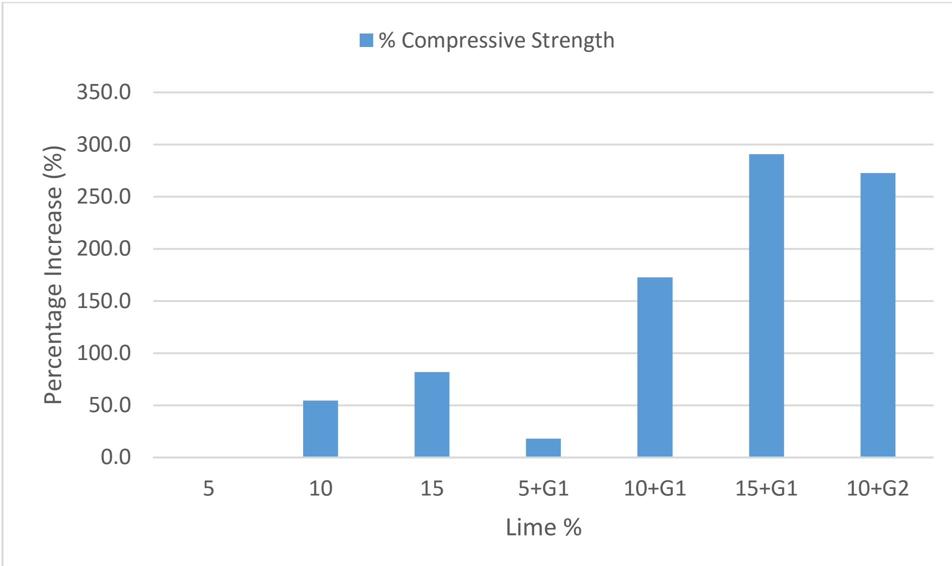


Fig 42: 3 days curing

6.2.2 For 7 days curing period

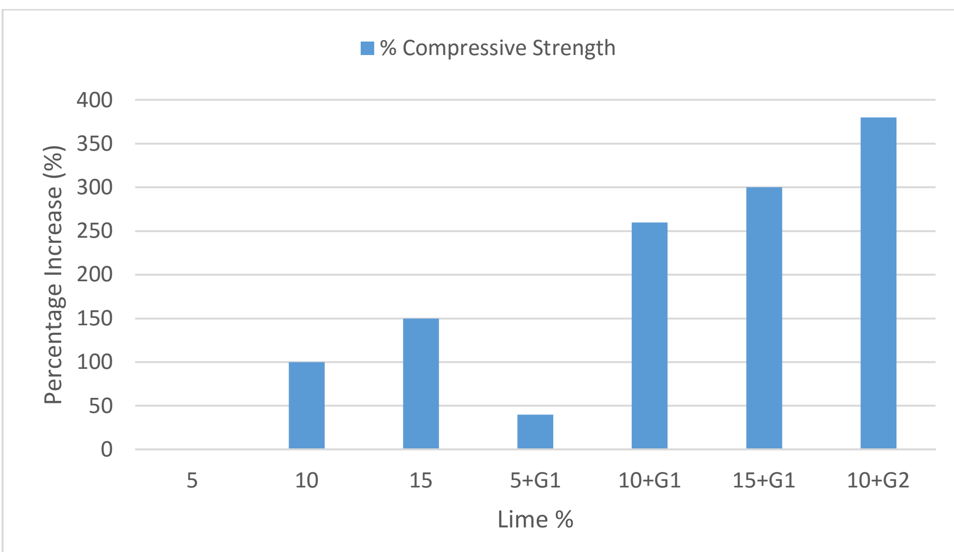


Fig 43: 7 days curing

Note: G1 means one layer of Geocomposite and G2 means two layers of Geocomposite

6.2.3 For 14 days curing period

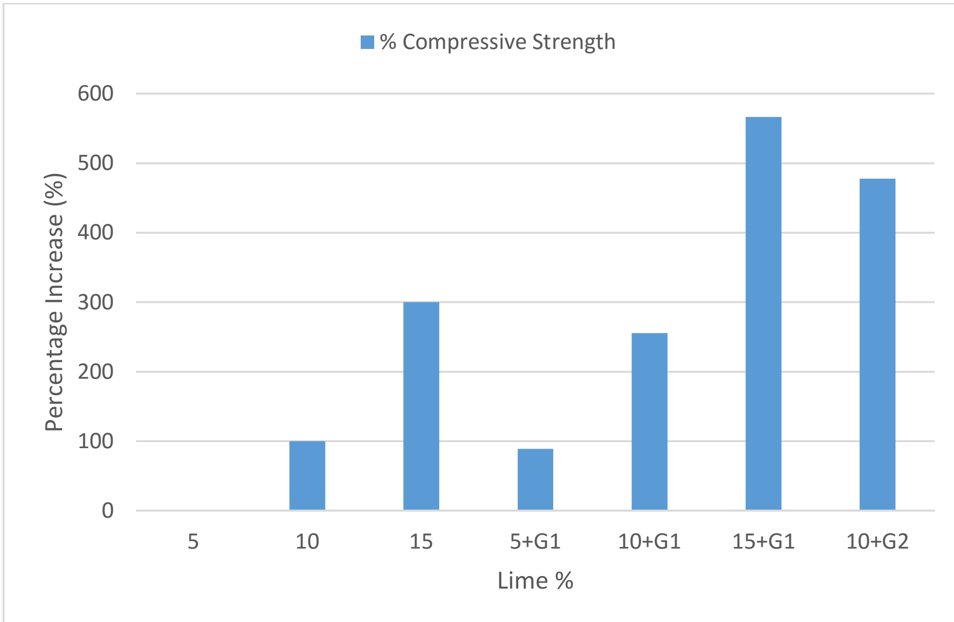


Fig 44: 14 days curing

6.2.4 For 28 days curing period

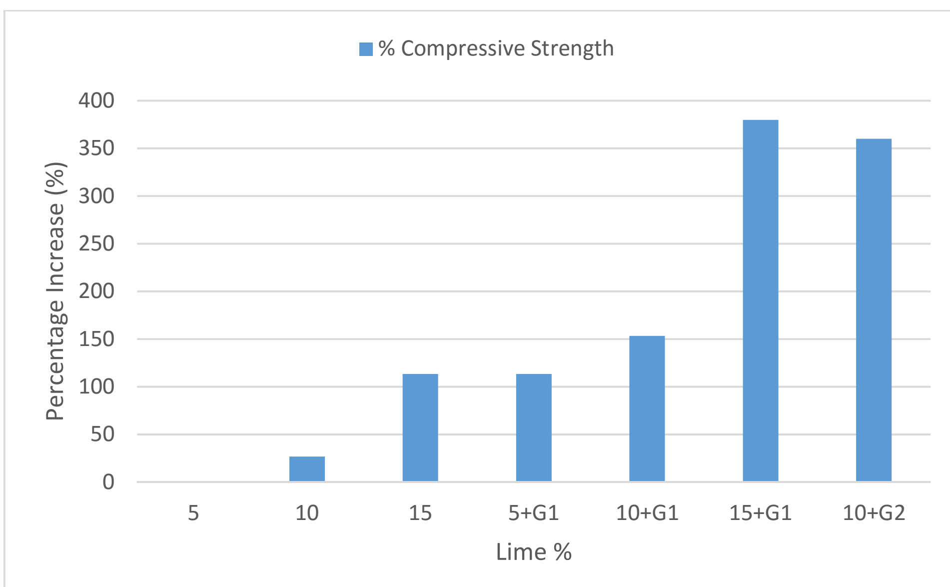


Fig 45: 28 days curing

Note: G1 means one layer of Geocomposite and G2 means two layers of Geocomposite

6.3 Comparison of increase in Compressive Strength with respect to days of Curing Period

6.3.1 For 5% lime content

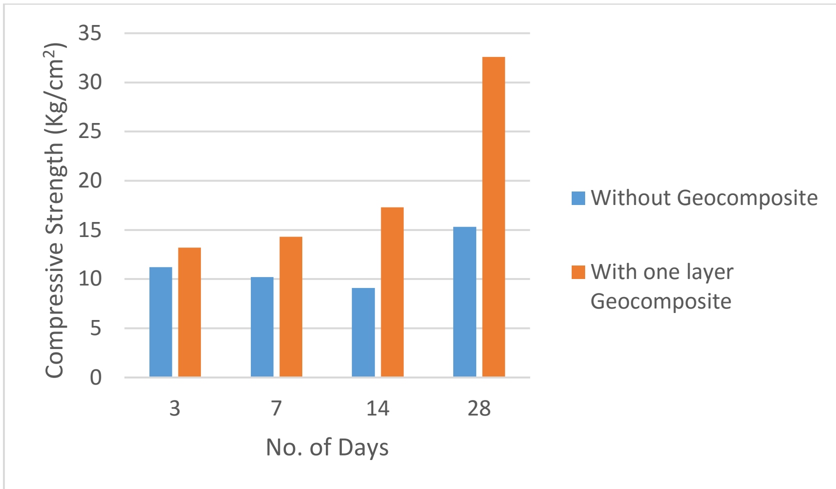


Fig.46 Increase in compressive strength of Black Cotton soil blocks with respect to days of curing period for 5% lime content

6.3.2 For 10% lime content

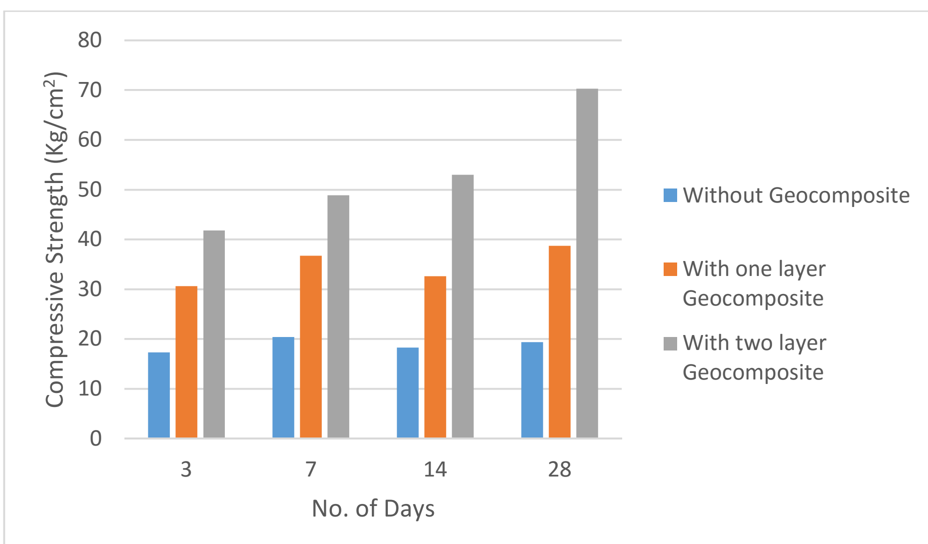


Fig.47 Increase in compressive strength of Black Cotton soil blocks with respect to days of curing period for 10% lime content

6.3.3 For 15% lime content

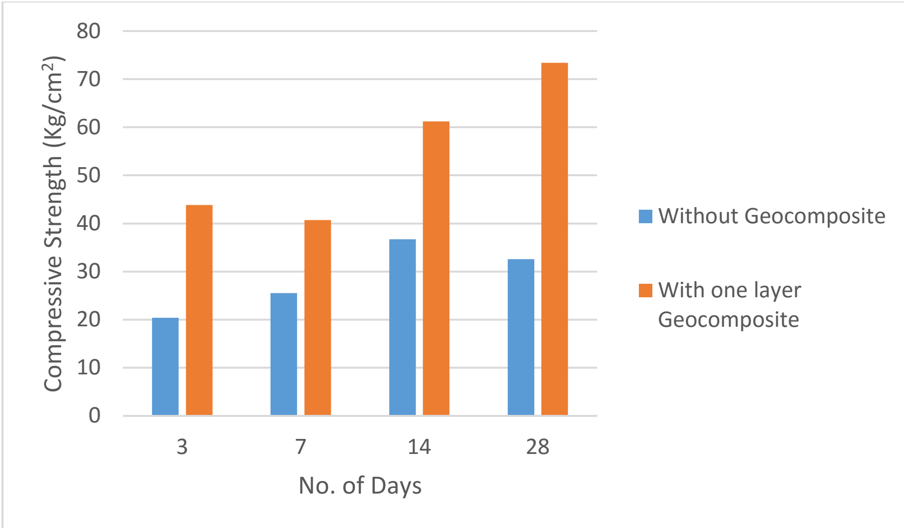


Fig.48 Increase in compressive strength of Black Cotton soil blocks with respect to days of curing period for 15% lime content

6.4 Discussions

- From Fig. 27, we found that the compressive strength of normal Black Cotton Soil cubes was 6.985 kg/cm^2. In order to increase the strength, Lime was added to the Black Cotton Soil. Three different percentages of lime was added and it was found that 15% lime content at 14 days of curing period yields maximum strength of 36.7 kg/cm^2 as shown in Fig. 48.
- In order to further increase the strength, a layer of Geocomposite was added to the mixture of Black Cotton Soil and Lime Blocks. From tests, it was found that there was a further increase in compressive strength and the maximum strength of Black Cotton Soil cubes with one layer of Geocomposite and 15% lime content at 28 days of curing period was 73.4 kg/cm^2 as shown in Fig. 48.
- Futher an attempt was made to see the percentage increase in Compressive Strength with addition of another layer of Geocomposite. So we added a second layer of Geocomposite to the Black Cotton Soil cubes with 10% Lime content and found that the Compressive Strength of cubes increased from 38.7 kg/cm^2 to 70.3 kg/cm^2 at 28 days of curing period (Fig. 47) showing a percentage increase of 81.6%.

- From Fig.42, the percentage increase in compressive strength of Black Cotton soil cubes with respect to 5% Lime content for curing period of 3 days for 10%, 15%, 5% with one layer of Geocomposite, 10% with one layer of Geocomposite, 15% with one layer of Geocomposite and 10% with two layer of Geocomposite was 54.5%, 81.8%, 18.2%, 172.7%, 290.9% and 272.7% respectively. It has observed that, **for 15% addition of lime with one layer of geocomposite reinforcement the percentage increase in compressive strength was highest.**
- From Fig.43, the percentage increase in compressive strength of Black Cotton soil cubes with respect to 5% Lime content for curing period of 7 days for 10%, 15%, 5% with one layer of Geocomposite, 10% with one layer of Geocomposite, 15% with one layer of Geocomposite and 10% with two layer of Geocomposite was 100%, 150%, 40%, 260%, 300% and 380% respectively. It has observed that, **for 10% addition of lime with two layer of geocomposite reinforcement the percentage increase in compressive strength was highest.**
- From Fig .44, the percentage increase in compressive strength of Black Cotton soil cubes with respect to 5% Lime content for curing period of 14 days for 10%, 15%, 5% with one layer of Geocomposite, 10% with one layer of Geocomposite, 15% with one layer of Geocomposite and 10% with two layer of Geocomposite was 100%, 300%, 88.9%, 255.6%, 566.7% and 477.8% respectively. It has observed that, **for 15% addition of lime with one layer of geocomposite reinforcement the percentage increase in compressive strength was highest.**
- From Fig.45, the percentage increase in compressive strength of Black Cotton soil cubes with respect to 5% Lime content for curing period of 28 days for 10%, 15%, 5% with one layer of Geocomposite, 10% with one layer of Geocomposite, 15% with one layer of Geocomposite and 10% with two layer of Geocomposite was 26.7%, 113.3%, 113.3%, 153.3%, 380% and 360% respectively. It has observed that, **for 15% addition of lime with one layer of geocomposite reinforcement the percentage increase in compressive strength was highest.**
- With addition of Lime and Geocomposite, the Compressive Strength of Black Cotton Soil increases and therefore using these two simultaneously provides maximum strength.

CHAPTER 7: SCOPE FOR FUTURE WORK

Future work can be carried out on this project. Some ways are

- Use of organic soils in spite of black cotton soil as they have a lot of similarities to the black cotton soil and their usage and applications are very wide.
- Many other geotechnical tests can be performed like Triaxial Test, California Bearing Ratio, Swelling Index and Consolidation Test that we left out.
- Use of different percentages of lime. We have taken 5%, 10% and 15% of lime. Other work can be carried out taking a lot of combinations of different percentages of lime.
- Use of different type of geosynthetics. We used geocomposite in out project. Other work can be carried out taking geogrids or geonets or even with geotextiles.
- Use of different layers of reinforcement inside the cube. We have used one and two layers of reinforcement from the bottom of the cube. Other work can be carried out by knowing the angle of shear failure of the cube and placing the reinforcement oriented in the direction of plane of shear failure.
- Use of another shape of blocks. Inspite of using cubical blocks, we can use rectangular blocks.

REFERENCES

[1] Madurwar K.V., Dahale P.P., Burile A.N., *Comparative Study of Black Cotton Soil Stabilization with RBI Grade 81 and Sodium Silicate,* International Journal of Innovative Research in Science, Engineering and Technology, Vol. 2, Issue 2, February 2013

[2] Pankaj R. Modak, Prakash B. Nangare, Sanjay D. Nagrale, Ravindra D. Nalawade, Vivek S. Chavhan, *Stabilisation of Black Cotton Soil Using Admixtures*, International Journal of Engineering and Innovative Technology (IJEIT), Volume 1, Issue 5, May 2012

[3] Nadgouda, K.A., Hegde, R.A., Dept. of Civil Engineering Sardar Patel College of Engineering, Mumbai, *The Effect of Lime Stabilization on Properties of Black Cotton Soil*, Indian Geotechnical Conference – 2010, GEOtrendz December 16–18, 2010

[4] Sujit Kawade, Mahendra Mapari, Shreedhar Sharanappa, *Stabilization of Black Cotton Soil with Lime and Geo-grid*, International Journal of Innovative Research in Advanced Engineering (IJIRAE), Volume 1 Issue 5 (June 2014)

[5] Kavish S. Mehta, Rutvij J. Sonecha, Parth D. Daxini, Parth B. Ratanpara, Miss Kapilani S. Gaikwad, *Analysis of Engineering Properties of Black Cotton Soil & Stabilization Using By Lime*, Int. Journal of Engineering Research and Applications ISSN : 2248-9622, Vol. 4, Issue 5(Version 3), May 2014, pp.25-32

[6] V. R. Bharambe, Prof. G. K. Patil, *A Study on Stabilzation of Black Cotton Soil Using Ferric Chloride*, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 10, Issue 1 (Nov. - Dec. 2013), PP 26-30

[7] Arun Patidar, Dr. H.K. Mahiyar, *An Experimental Study of Black Cotton Soil Using HDPE Wastage Fibres, Stone Dust and Lime*, International Journal of Advanced Scientific and Technical Research Issue 4 volume 6, Nov. – Dec. 2014

[8] Neetu B. Ramteke, Prof. Anilkumar Saxena, Prof. T. R. Arora, *A Review: Effect of Geo-grid reinforcement on soil*, International Journal Of Core Engineering & Management(IJCEM) Volume 1, Issue 4, July 2014

[9] Kaushal Vinayak, Guleria S.P., *Geotechnical Investigations on Black Cotton Soils*, International Journal of Advances in Engineering Sciences Vol.5, Issue 2, April, 2015

[10] Dilip Shrivastava, A K Singhai, R K Yadav, *Effect of Lime and Rice Husk Ash on Engineering Properties of Black Cotton Soil*, Int. Journal of Engineering Research and Applications ISSN 2319-5991, Vol. 3, No. 2, May, 2014

[11] Pramod Kilabanur, Tanveer Ahmad, Dorothy Bhagabati, Nitesh Kumar, Yasaswini S, *Stabilization Of Black Cotton Soil Using Envirobase And Sodium Silicate With Lime*, International Journal of Advanced Scientific and Technical Research Volume 4, Issue 06, June 2015

[12] H.N.Ramesh, A.J.Krishnaiah, S.Shilpa shet, *Effect of Lime on the Index Properties of Black Cotton Soil and Mine tailings mixtures*, IOSR Journal of Engineering (IOSRJEN), Vol. 3, Issue 4 (April. 2013)

[13] Gopal Ranjan and A. S. R. Rao, Basic and Applied Soil Mechanics, 2nd ed., Reprint 2014, New Age International (P) Limited, Publishers, New Delhi

[14] (2010) Soil map of India webpage. [Online].
Available: http://www.mapsofindia.com/maps/india/soilsofindia.htm